BMJ Open

Objectively measured physical activity in Finnish employees: a cross-sectional study

Journal:	*BMJ Open*
Manuscript ID:	bmjopen-2014-005927
Article Type:	Research
Date Submitted by the Author:	17-Jun-2014
Complete List of Authors:	Mutikainen, Sara; University of Jyvaskyla Helander, Elina; Tampere University of Technology, Department of Signal Processing Pietilä, Julia; Tampere University of Technology, Department of Signal Processing Korhonen, Ilkka; Tampere University of Technology, Department of Signal Processing Kujala, Urho; University of Jyväskylä, Department of Health Sciences
Primary Subject Heading:	Sports and exercise medicine
Secondary Subject Heading:	Public health, Occupational and environmental medicine, Rehabilitation medicine, Epidemiology
Keywords:	Physical activity, Obesity, Exercise intensity, Heart rate variability, Objective monitoring

Objectively measured physical activity in Finnish employees: a cross-sectional study

Sara Mutikainen, Elina Helander, Julia Pietilä, Ilkka Korhonen, Urho M. Kujala

Department of Health Sciences, University of Jyväskylä, Jyväskylä, Finland Sara Mutikainen post-doctoral researcher, Urho M Kujala professor

Department of Signal Processing, Tampere University of Technology, Tampere, Finland Elina Helander post-doctoral researcher, Julia Pietilä research assistant, Ilkka Korhonen professor

VTT Technical Research Center of Finland, Tampere, Finland Ilkka Korhonen professor

Correspondence to:

Urho M. Kujala, M.D., Ph.D., Department of Health Sciences, University of Jyväskylä, P.O.Box 35 (LL), FI-40014 University of Jyväskylä, Finland

Tel: +358408053567, Fax: +35814617423, E-mail: urho.m.kujala@jyu.fi

Abstract

Objectives - To objectively measure the amount of intensity-specific physical activity by gender and age with respect to body mass index (BMI) during workdays and days off among Finnish employees.

Design – A cross-sectional study.

Setting – Primary care occupational health care units.

Participants - A sample of 9554 Finnish employees (4221 men and 5333 women; age range 18-65 years; BMI range 18.5-40.0 kg/m^2) who participated in health assessments related to occupational health promotion.

Main outcome measurements – The amount of moderate-to-vigorous (MVPA) and vigorous (VPA) physical activity (≥3 and ≥6 metabolic equivalents, respectively) was assessed by estimating minute-to-minute oxygen consumption from the recorded beat-to-beat R-R interval data. The estimation method used heart rate, respiration rate, and on/off response information from R-R interval data calibrated by age, gender, height, weight, and self-reported physical activity class. The proportion of participants fulfilling the physical activity recommendation of ≥150 minutes/week was calculated on the basis of ≥10-minute bouts, multiplying VPA minutes by 2.

Results – Both MVPA and VPA were higher among men and during days off, and decreased with increasing age and BMI (P<0.001 for all). Similar results were observed when the probability of having a bout of MVPA or VPA lasting continuously for ≥10 minutes per measurement day was studied. The total amount of VPA was very low among overweight (mean ≤2.6 minutes/day), obese (mean ≤0.6 minutes/day), and all 51 to 65-year-old (mean ≤2.5 minutes/day) women during both types of days. The proportion of participants fulfilling the physical activity recommendation was highest for normal weight men (65%; 95% CI 62 to 67%) and lowest for obese women (10%; 95% CI 8 to 12%).

Conclusions – Objectively measured physical activity is higher among men and during days off and decreases with increasing age and BMI. The amount of VPA is very low among obese, overweight, and older women.

Strengths and limitations of this study

- Using novel validated methodology, our study provides accurate data on intensity-specific physical activity in a large sample of working age individuals, with detailed associations between intensity-specific physical activity and gender, age, body mass index (BMI), and the type of day (workday vs. day off) and their interactions.
- We found that higher BMI and higher age decrease the likelihood of participating in moderate-to-vigorous and vigorous physical activity, and BMI affects older participants more than younger participants.
- A very low proportion of obese (particularly women) participants met the physical activity recommendation, and the amount of vigorous physical activity is very low in this subgroup.
- The study sample was not a random sample from the population, but a 'real life' clinical sample of employees who participated in preventive occupational health care.
- Our recordings usually covered some typical workdays and days off, a longer recording may be more valid than the duration used in our study.

Introduction

Epidemiological evidence, studies on underlying mechanisms, and intervention studies suggest that physical activity plays an important role in the prevention of body fat accumulation and type 2 diabetes.[1-5] To achieve these health benefits, according to recent recommendations, moderate intensity physical activity should be performed for at least 150 minutes or vigorous physical activity at least 75 minutes per week.[3 6 7] However, accurately recording the amount and intensity of physical activity with regard to both physical activity-related energy requirements and cardio-respiratory loading is challenging.[8 9] Objective information is usually obtained by heart rate (HR) monitors or motion sensors, such as accelerometers.[10] Existing data suggest that, among obese individuals, the amount of vigorous physical activity is low compared to current recommendations.[9 11-13] However, estimating the cardio-respiratory loading of physical activity among obese and/or unfit individuals is difficult using accelerometers or other motion sensors.

HR monitoring is a common method of assessing the intensity of physical activity in clinical settings. HR is almost linearly associated with oxygen consumption (VO_2) at moderate to submaximal intensities in steady-state exercise; therefore, it can be used to estimate the intensity of steady-state physical activity. However, the intensity of real life physical activity usually changes repeatedly, and the relationship between HR and VO_2 is curvilinear for very low intensity physical activities and near maximal exercise; thus, the actual VO_2 can be over- or underestimated when using the linear HR-VO_2 relationship to estimate the actual VO_2.[14] Continuous measurement of HR variability and experimental calibration of data by age, gender, weight, height, and self-reported physical activity class was recently shown to provide accurate estimates of the intensity of physical activity.[15] We used such novel methodology in this study to estimate the intensity of physical activity in a large sample of Finnish employees.

The aim of this study was to investigate the amount of physical activity among 9554 Finnish employees who had participated in continuous beat-to-beat R-R interval (ECG) recordings during the course of their normal everyday life. More specifically, we investigated the intensity-specific amount of physical activity by gender and age with respect to body mass index (BMI) during workdays vs. days off, including hourly distributions of physical activity throughout the day. This information is an important basis for understanding the cardio-respiratory loading caused by physical activity and the needs and realistic possibilities for interventions that increase physical activity.

Methods

Study design and participants

This study is a cross-sectional study investigating the intensity and amount of physical activity among a clinical sample of 9554 Finnish employees (4221 men and 5333 women; age range 18-65 years; BMI range 18.5-40.0 kg/m^2) who participated in preventive occupational health care provided by their employers during the years 2007-2013 (Figure 1). The participants non-selectively represent a wide range of non-manual and manual labor employees and, thus, a cross-section of typical Finnish employees. As a part of these health care programs, participants performed continuous beat-to-beat R-R interval recordings in the course of their normal everyday life as described below. The clinical purpose of these recordings was to assess the intensity and amount of physical activity (reported in this paper) and other R-R interval -derived information such as the amount of stress and recovery[16] (not reported in this paper) during workdays and days off. To acquire these so-called Lifestyle Assessment results, the R-R interval data were analyzed using Firstbeat Analysis Server software (Firstbeat Technologies Ltd, Jyväskylä, Finland). On the basis of the results, the participants received personal feedback and recommendations for maintaining or improving their health and wellbeing.

The majority of the participants in this study were apparently healthy. The exclusion criteria for participation in the R-R interval recordings represented by the analysis software manufacturer were: chronic rhythm disturbance, cardiac pacemaker or transplant, left bundle branch block, severe cardiac disease (e.g., symptomatic coronary heart disease, heart failure), very high blood pressure (≥180/100 mmHg), type 1 or 2 diabetes with autonomic neuropathy, hyperthyreosis or other disturbances of the thyroid gland leading to a resting HR >80 bpm, severe neurological disease (e.g., advanced multiple sclerosis or Parkinson's disease), fever or other acute disease, and BMI >40.0 kg/m^2. Cases of milder/early disease stages and some medications may affect R-R intervals or physical activity levels. The inclusion/exclusion of these participants from the R-R interval recordings was evaluated on a case-by-case basis in the occupational health care programs.

The data obtained from these R-R interval recordings were analyzed and anonymously stored in a database administered by the software manufacturer (Firstbeat Technologies Ltd). Firstbeat Technologies Ltd and each service provider (e.g., occupational health care unit) who conducted the recordings for employees (participants) signed an agreement providing Firstbeat Technologies Ltd the right to store the data in an anonymized form and to use it for development and research purposes with a statement that employers must inform their employees about its use. According to the agreement, Firstbeat Technologies Ltd extracted an anonymous data file from the registry for the present research purposes.

Physical activity assessment

The ambulatory beat-to-beat R-R interval data used to calculate the intensity and amount of physical activity were recorded during the course of normal everyday life, usually over 3 days (typically including two workdays and one day off), using the Firstbeat Bodyguard device (Firstbeat Technologies Ltd). Data from the measurements were analyzed using Firstbeat Analysis Server software (version 5.6.0.3, Firstbeat Technologies Ltd). To be included in the analyses (Figure 1), a participant had to have a measurement period including at least one workday and one day off. We included a workday or a day off in the analysis if the measurement period lasted >16 hours/day. The information about workdays and days off was obtained from the diaries the participants were asked to fill in during the measurement period. A day was considered to be a workday if a participant worked ≥4 hours cumulatively. The days without any working hours were regarded as days off and the days with work time < 4 hours were excluded from the analyses. The analyzed data consisted of successfully recorded (measurement error <15% and <30 minute recording break) workdays and days off (Figure 1).

Background information included age, gender, self-reported height and weight, and self-reported physical activity class. [17,18] This information was collected in conjunction with R-R interval recordings using questionnaires. Background information was used to estimate maximal HR and maximal VO_2, which were used in the estimation of VO_2. For the statistical analyses, BMI was calculated from the self-reported weight and height as kilograms per meters squared.

The intensity and amount of physical activity was estimated based on the R-R interval recordings.[19-22] The method was validated previously; the pooled relationship (correlation) between the measured and predicted VO_2 across the different activities of daily living was

0.93 and the estimated VO_2 explained 87% of the variability in the measured VO_2.[15] The high validity of this method was achieved by taking into account the R-R interval-derived information about HR, respiration rate, and on/off response (increasing or decreasing HR) using neural network modeling of the data and short time Fourier Transform method.[19-22]

The participant's mean VO_2 for each minute during each measurement day was calculated from the second-by-second VO_2 estimations. The minute-by-minute VO_2 estimations were then converted to multiples of the resting metabolic rate (METs) by dividing the VO_2 values by 3.5. Based on the MET values, the amount of physical activity (minutes/day) at a certain intensity level was calculated two ways. First, we searched the recordings for single 1-minute segments in which the intensity reached the following MET thresholds: moderate physical activity (MPA) 3 to <6 METs, vigorous physical activity (VPA) ≥6 METs, and moderate-to-vigorous physical activity (MVPA) ≥3 METs,[7] which are referred to as MPA_{1min}, VPA_{1min}, and $MVPA_{1min}$ later in the text. The total number of 1-minute segments above the given thresholds during each measurement day was then calculated. These calculations were performed separately for workdays and days off. If a participant's measurement period included two or more workdays (or days off), an average was calculated. Second, because the recommendation for health-enhancing physical activity suggests that the duration of a bout of aerobic activity should be 10 continuous minutes or longer,[3 6 7] we utilized this in our calculations for different intensity categories, which are referred to as MPA_{10min}, VPA_{10min}, and $MVPA_{10min}$ later in the text. In this case, we calculated the total number of 1-minute segments above the given intensity thresholds during each measurement day using only the bouts of physical activity that lasted continuously for ≥10 minutes. The consecutive 1-minute segments had to be above the given intensity thresholds for at least 10 minutes, except for one 1-minute segment, which was allowed to be less than the given threshold. Otherwise the calculations were performed using the same principles as described above for single 1-minute segments.

Analysis

Data processing and statistical analysis were performed using MATLAB version R2013b (The MathWorks Inc., Natick, Massachusetts, U.S.A.) and R version 3.0.2 (The R Foundation for Statistical Computing, Vienna, Austria). All P values were two-sided and $P<0.05$ was considered statistically significant.

We calculated means, standard deviations, and medians for continuous variables and frequencies and proportions for categorical variables. We categorized the amount of MVPA and VPA into four categories (0, >0 to 15, >15 to 30 and >30 min) and calculated the distribution of participants in these categories by gender and type of day (i.e., workdays vs. days off). We also calculated the amount of MVPA and VPA by gender and type of day for different age categories (18-30, 31-40, 41-50, and 51-65 years) and BMI categories (normal weight 18.5 to <25.0 kg/m^2, overweight 25.0 to <30.0 kg/m^2, and obese 30.0 to 40.0 kg/m^2). The amount of MVPA and VPA during the workdays and days off were compared by gender inside each age and BMI category using the Wilcoxon two-sample paired signed rank test. The test assessed whether the differences in the amount of MVPA and VPA between each participant's workdays and days off came from a distribution with a median of zero. Differences in the amount of MVPA and VPA between age categories and between BMI categories were analyzed using the Kruskal-Wallis test. To describe the temporal distribution of physical activity, we calculated the amount of MVPA and VPA in each hour (e.g., from 9 am to 10 am, from 10 am to 11 am, etc.) during the day by gender, BMI category, and type of day. For illustrative reasons, the means are shown in all figures instead of medians.

The probability of having at least one 10-minute bout of MVPA or VPA per measurement day (binary outcome; yes vs. no) was modeled using a generalized linear mixed effects regression (procedure *glmer* with Laplace approximation in R). Each participant was incorporated as a random effect, and fixed effects included age and BMI as continuous variables and gender and type of day as binary variables. In the modeling, we also included all of the possible two-way interactions among these four variables. We also used linear mixed effects regression (procedure *fitlme* with maximum likelihood estimation in MATLAB) to predict the amount of $MVPA_{1min}$ and VPA_{1min}. In this case, each participant was incorporated as a random effect and fixed effects included age, BMI, gender, and type of day. The baselines for age (minimum 18) and BMI (minimum 18.5) were subtracted from age and BMI data, respectively, before regression calculations.

We also investigated how participants fulfill the physical activity recommendations of moderate intensity physical activity at least 150 minutes per week or vigorous physical activity at least 75 minutes per week as measured from ≥10-minute bouts of activity.[3] First, we calculated the activity minutes score for each day (MPA minutes + VPA minutes x 2) and then extrapolated the amount of physical activity using the following formula: Weekly physical activity = (5 x mean workday activity score) + (2 x mean day off activity score). This calculation was performed with only the bouts of physical activity lasting continuously for ≥10 minutes as recommended,[3] and then with all ≥1-minute bouts.

Results

Most of the R-R-interval recordings were from 3 days (7685 participants); there were 1394, 319, 119, and 37 participants who had two, four, five, and six measurement days, respectively. Altogether, the number of analyzed days was 17020 for workdays and 10916 for days off. The mean (SD) age of the participants was 44.8 (9.7) years [men 44.7 (9.7); women 44.9 (9.7)] and the mean (SD) BMI was 26.1 (4.1) kg/m^2 [men 26.7 (3.5); women 25.7 (4.4)].

Table 1 shows the distributions of participants into the MVPA and VPA categories by workdays and days off among the 4221 men and 5333 women who participated in this study. For more than 60% of men and approximately 40% of women, the amount of $MVPA_{1min}$ was more than 30 minutes per day, regardless of the type of day, whereas 11% (workdays) and 18% (days off) of men and 4% (workdays) and 8% (days off) of women had VPA_{1min} for more than 30 minutes per day. All these percentages were clearly lower for $MVPA_{10min}$ and VPA_{10min}.

Figure 2 and Table 2 show the amount of MVPA and VPA by age, gender, and the type of day. The amount of MVPA and VPA decreased with advancing age, especially among women. Among men aged 31 years and older, the amounts of $MVPA_{1min}$, $MVPA_{10min}$, VPA_{1min}, and VPA_{10min} were greater during days off than during workdays. Among younger women (18-40 years), the amount of $MVPA_{1min}$ was lower during days off compared to working days, whereas the amount of $MVPA_{10min}$ was higher during days off among older women (41-65 years). Other clear trends were not observed among women.

Figure 3 and Table 3 show the amount of MVPA and VPA by weight status, gender, and the type of day. Obese participants had less MVPA and VPA than normal weight and overweight participants, especially women. The mean amount of VPA_{1min} was approximately 0.5 minutes per day among obese women, for both workdays and days off. Among obese men, the mean amount of VPA_{1min} was 5.0 minutes during workdays and 6.1 minutes during days off. The mean amount of VPA_{1min} was also low among overweight women (~2.5 minutes per day for both workdays and days off). Among normal weight and overweight men, the amount of $MVPA_{1min}$, $MVPA_{10min}$, VPA_{1min}, and VPA_{10min} were all greater during days off than workdays, but these differences were not observed among obese men. The corresponding results for women were more complex. Normal weight and overweight women had more $MVPA_{10min}$ during days off than during workdays. However, the amount of $MVPA_{1min}$ was similar between the types of days. On the other hand, obese women had a lower amount of $MVPA_{1min}$ during days off than workdays, but the amount of $MVPA_{10min}$ was similar between the types of day. Differences between workdays and days off with regard to VPA were observed for normal weight women; VPA_{10min} was higher during days off than workdays.

Hourly distributions of MVPA and VPA by gender, weight status, and type of day are shown in Figure 4. The largest amounts of MVPA during workdays occurred at 7-8 am and 5-7 pm. During days off, the largest amounts of MVPA were distributed evenly between 10 am and 6 pm. The respective VPA profiles resemble those of MVPA. During workdays, a small peak occurred at 7-8 am, but the greatest amount of VPA was clearly seen at 5-8 pm. The greatest amount of VPA during days off occurred between 10 am and 8 pm. For both genders, the amount of MVPA and VPA during workdays and days off decreased with increasing BMI.

When age, gender, BMI, and the type of day were included in the linear mixed effects regression models as predictors of the amount of $MVPA_{1min}$ or VPA_{1min} (Table 4), the predictors associated with both outcome measures in similar manners. The amount of $MVPA_{1min}$ and VPA_{1min} decreased with increasing age and increasing BMI. The amounts of $MVPA_{1min}$ and VPA_{1min} were higher among men compared to women and higher during days off than during workdays ($P<0.001$ for all). Similar results were observed when we studied the probability of having a bout of MVPA or VPA (per measurement day) that lasted continuously for ≥10 minutes (Table 5). The probability was higher among men and during days off, and it decreased with increasing age and increasing BMI ($P<0.001$ for all).

We also performed multivariate analysis for the probability of having a bout of MVPA or VPA lasting continuously for ≥10 minutes including two-way interactions between age, gender, BMI, and the type of day (Table 5). Many statistically significant interactions were observed between these variables. Both higher BMI and higher age decreased the likelihood of participating in MVPA or VPA, but BMI affected older participants more than younger participants. In addition, women were more affected by higher age or higher BMI than men. With increasing age, the probability of MVPA or VPA increased for days off compared to workdays. With increasing BMI, the probability of MVPA and VPA increased for workdays compared to days off.

The percentages of participants (by gender and weight status) who fulfilled the physical activity recommendations are provided in Figure 5 and Table 6. The proportion of participants fulfilling the recommendations decreased with increasing BMI for both men and women. The same was true when the weekly physical activity was calculated including all ≥1-minute bouts. Men fulfilled the recommendations better than women. The proportion fulfilling the recommendations was highest among normal weight men (64.9%, 95% CI 62.4 to 67.3 when ≥10-minute bouts were included in the calculation and 88.6%, 95% CI 86.8 to 90.1 when ≥1-minute bouts were included) and lowest among obese women (10.3%, 95% CI 8.4 to 12.4 and 23.0%, 95% CI 20.3 to 25.8, respectively).

Discussion

We found that the amount of physical activity decreases with increasing age and increasing BMI for both genders, but with a deeper decline among women. The amount of VPA was particularly low among older (51-65 years) and obese and overweight women. Men had more physical activity than women, and physical activity was more common during days off than during workdays, especially among men. The hourly distribution of physical activity clearly differed between workdays and days off. During workdays, physical activity was most common early in the morning and right after working hours, whereas physical activity was distributed more evenly throughout the day during days off. In addition, the proportion of participants fulfilling the physical activity recommendations decreased with increasing BMI and was lower for women than for men. Approximately one-third of the obese men and one-tenth of obese women fulfilled the physical activity recommendations.

Strengths and weaknesses of the study

Our study has several strengths. First, our study sample was very large and included a wide range of non-manual and manual labor employees. Therefore, this sample can be considered to represent a cross-section of typical Finnish employees. Second, we used a novel ambulatory beat-to-beat R-R interval-based method to assess the intensity of physical activity. This method has been shown to provide more accurate estimates of the intensity of physical activity than HR information only.[15 22] Third, we had strict criteria for the inclusion of recording days (e.g., measurement error <15% and recording break <30 minutes); thus, our recordings had good coverage of typical workdays and days off. Consequently, we expect that the values represent our target population well. Nonetheless, our study also has some weaknesses. Most of the participants were apparently healthy, but some participants with chronic diseases and/or medications that do not severely affect HR were also included in the sample of employees. We did not adjust for these conditions in the analysis. In addition, the study sample was not a random sample from the population, but a ‘real life’ clinical sample of employees who participated in preventive occupational health care. This can be considered as either a strength or a weakness depending on the perspective. Our method for assessing physical activity can differentiate between the intensities of physical activity MET by MET, but to simplify our presentations, we used cut-off points of ≥3 and ≥6 METs to describe

MVPA and VPA, respectively, as these are used in the physical activity recommendations.[7] To accurately assess individual long-term physical activity levels, a longer recording is more valid than the duration used in our study.[23] Our recordings usually covered some typical workdays and days off, as our aim was to obtain recordings covering most of the day without artifacts. To achieve this goal, stick-on electrodes with wires were used for the collection of R-R interval data, but in some individuals, the electrodes cause skin irritation that make it difficult to make long recordings.

Findings in relation to other studies

The majority of previous studies including large study populations used accelerometers or pedometers for the objective assessment of physical activity. These methods provide rough estimates of the intensity of physical activity. We used beat-to-beat R-R interval data, which allows more accurate estimations of the intensity of physical activity, but it also has limitations when comparing our results to previous results. The age- and BMI-associated declines in the amount of physical activity observed in our study are in agreement with the results of the studies using accelerometers.[9 12 13 24] In our study, the amount of VPA was very low, especially among older women and overweight and obese women, and similar results have been reported in previous studies that used accelerometers.[9 12 24] Our results on the clear difference between workdays and days off in the hourly distribution of physical activity are in accordance with previous studies.[13] In addition, we observed that the proportions of overweight and obese participants fulfilling the physical activity recommendations are lower than the proportion of normal weight participants. Previous studies obtained similar results showing that among obese individuals especially the amount of VPA is low compared with the current recommendation.[9 11 13] Overall, most of the associations in our study are similar to previous population-based studies that used accelerometers. However, our method measures cardio-respiratory loading more directly than the methods based on motion sensors. The amount of physical activity calculated from the bouts lasting ≥10 minutes should be used when determining who meets the current physical activity recommendations.[3] We calculated the amount of MVPA and VPA in two different ways that reflect different aspects of physical activity. The amount of physical activity calculated from single 1-minute bouts throughout the measurement period may be considered to reflect daily activities rather than fitness-enhancing exercise, as this method also takes into account very short bouts of physical activity, such as climbing stairs. Interestingly, the proportion of participants fulfilling the recommendation is doubled when shorter bouts are included in the calculation (Table 5).

Meaning of the study: implications for clinicians and policymakers

Increasing physical activity and reducing obesity are both important targets for improving overall population health, as both obesity and low physical activity are predictors of mortality.[25] According to our study approximately one-third of Finnish working-aged women and half of working-aged men meet the current recommendations for physical activity. The proportion is especially low among overweight and obese women and obese men. On the basis of this and our other observations, the amount of physical activity, especially the amount of VPA, seems to be very low among overweight and obese individuals, particularly women. As our study is cross-sectional in nature, it does not show the direction of causality between physical activity and obesity. However, this evidence shows the vicious cycle between obesity and physical inactivity.[26] The low number of obese individuals meeting the recommendations and their low starting level (with regard to total amount, duration, and intensity) should be taken into account when tailoring interventions for increasing physical activity. For obese individuals, the amount of MPA should be increased first. Among obese individuals, objectively measured physical activity seems to be low both during leisure and at work. Thus, both leisure hours and working hours need attention when tailoring activity interventions. Overall, the documentation of physical activity levels as a part of routine health care should be improved.[27]

Unanswered questions and future research

In light of our findings, long-term controlled intervention studies are needed to show whether MPA or VPA as the main component of intervention programs has a better benefit-risk balance among obese individuals in terms of adherence, weight-control, morbidity, and mortality. Also, more detailed research is needed on whether short bouts of physical activity lead to long-term health benefits comparable to longer bouts at the disease-outcome level. Accurate methods of monitoring physical activity that cover cardio-respiratory loading are also needed to carry out large-scale studies on these topics and to analyze whether specific types of short-term activity provide health benefits. Notably, some physical activity is under the intensity level of 3 METs, which was not taken into account in our current analysis. Long-term intervention studies on the effects of physical activity with (very) low intensity on disease outcomes are lacking.

Footnotes

We thank Firstbeat Technologies Ltd for providing the data for analysis. We also thank Kaisa Hämäläinen, Jaakko Kotisaari, and Tero Myllymäki, Firstbeat Technologies Ltd, for their assistance in the first stages of data mining and their valuable comments on the methods section of this paper.

Contributors: All authors participated in planning the study design and statistical analyses, revision of the manuscript, and approved the final version. SM and UMK (guarantor) drafted the manuscript. EH and JP carried out the analysis. All researchers were independent of the funders. The study sponsor and funder played no role in study design; the collection, analysis, and interpretation of data; the writing of the report; and the decision to submit the article for publication.

Funding: This work was partially supported by the SalWe Research Program for Mind and Body (Tekes - the Finnish Funding Agency for Technology and Innovation grant 1104/10).

Ethical approval: This study was approved by the Ethics Committee of Tampere University Hospital (Reference No R13160).

Competing interests: All authors have completed the ICMJE uniform disclosure form at [www.icmje.org/coi_disclosure .pdf](http://www.icmje.org/coi_disclosure.pdf) and declare: all authors had financial support from Tekes (The Finnish Funding Agency for Innovation) for the submitted work; EH, JP and IK report research grant from Firstbeat Technologies Ltd, during the conduct of the study; EH, JP and IK report other research grant from Firstbeat Technologies Ltd, outside the submitted work; and IK is a co-founder in PulseOn Ltd which is a company developing optical heart rate monitoring technology, www.pulseon.com; other authors report no financial relationships with any organizations that might have an interest in the submitted work in the past three

years; other authors report no other relationships or activities that could appear to have influenced the submitted work.

Transparency: The lead author (the manuscript's guarantor) affirms that the manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

Data sharing: No additional data available.

An Exclusive licence: The Corresponding Author has the right to grant on behalf of all authors and does grant on behalf of all authors, a worldwide licence (http://www.bmj.com/sites/default/files/BMJ%20Author%20Licence%20March%202013.doc) to the Publishers and its licensees in perpetuity, in all forms, formats and media (whether known now or created in the future), to i) publish, reproduce, distribute, display and store the Contribution, ii) translate the Contribution into other languages, create adaptations, reprints, include within collections and create summaries, extracts and/or, abstracts of the Contribution and convert or allow conversion into any format including without limitation audio, iii) create any other derivative work(s) based in whole or part on the Contribution, iv) to exploit all subsidiary rights that currently exist or as may exist in the future in the Contribution, v) the inclusion of electronic links from the Contribution to third party material where-ever it may be located; and, vi) licence any third party to do any or all of the above. All research articles will be made available on an Open Access basis (with authors being asked to pay an open access fee—see http://www.bmj.com/about-bmj/resources-authors/forms-policies-and-checklists/copyright-open-access-and-permission-reuse). The terms of such Open Access shall be governed by a Creative Commons licence—details as to which Creative Commons

licence will apply to the research article are set out in our worldwide licence referred to above.

References

1. Pan XR, Li GW, Hu YH, Wang JX, Yang WY, An ZX, et al. Effects of diet and exercise in preventing NIDDM in people with impaired glucose tolerance. The Da Qing IGT and Diabetes Study. *Diabetes Care* 1997;20:537-44.
2. Ohkawara K, Tanaka S, Miyachi M, Ishikawa-Takata K, Tabata I. A dose-response relation between aerobic exercise and visceral fat reduction: Systematic review of clinical trials. *Int J Obes* 2007;31:1786-97.
3. Physical Activity Guidelines Advisory Committee. Physical Activity Guidelines Advisory Committee Report, 2008. Washington, DC: U.S. Department of Health and Human Services; 2008.
4. Waller K, Kaprio J, Lehtovirta M, Silventoinen K, Koskenvuo M, Kujala UM. Leisure-time physical activity and type 2 diabetes during a 28-year follow-up in twins. *Diabetologia* 2010;53:2531-7.
5. Kujala UM, Mäkinen V-P, Heinonen I, Soininen P, Kangas AJ, Leskinen TH, et al. Long-term leisure-time physical activity and serum metabolome. *Circulation* 2013;127:340-8.
6. World Health Organization. Global recommendations on physical activity for health. Geneva: World Health Organization; 2010.
7. Garber CE, Blissmer B, Deschenes MR, Franklin BA, Lamonte MJ, Lee I-M, et al. American College of Sports Medicine Position Stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: Guidance for prescribing exercise. *Med Sci Sports Exerc* 2011, 1334-59. doi:10.1249/MSS.0b013e318213fefb

8. Butte NF, Ekelund U, Westerterp KR. Assessing physical activity using wearable monitors: Measures of physical activity. *Med Sci Sports Exerc* 2012;44:S5-S12.
9. Archer E, Hand GA, Hébert JR, Lau EY, Wang X, Shook RP, et al. Validation of a novel protocol for calculating estimated energy requirements and average daily physical activity ratio for the US population: 2005-2006. *Mayo Clin Proc* 2013;88:1398-1407.
10. Westerterp KR. Assessment of physical activity: A critical appraisal. *Eur J Appl Physiol* 2009;105:823-8.
11. Hagströmer M, Oja P, Sjöström M. Physical activity and inactivity in an adult population assessed by accelerometry. *Med Sci Sports Exerc* 2007;39:1502-8.
12. Tucker JM, Welk GJ, Beyler NK. Physical activity in U.S. adults. Compliance with the Physical Activity Guidelines for Americans. *Am J Prev Med* 2011;40:454-61.
13. Hansen BH, Holme I, Anderssen SA, Kolle E. Patterns of objectively measured physical activity in normal weight, overweight, and obese individuals (20-85 years): A cross-sectional study. *PLos ONE* 2013;8(1):e53044. doi:10.1371/journal.pone.0053044
14. Achten J, Jeukendrup AE. Heart rate monitoring. Applications and limitations. *Sports Med* 2003;33:517-38.
15. Smolander J, Ajoviita M, Juuti T, Nummela A, Rusko H. Estimating oxygen consumption from heart rate and heart rate variability without individual calibration. *Clin Physiol Funct Imaging* 2011;31:266-71.
16. Teisala T, Mutikainen S, Tolvanen A, Rottensteiner M, Leskinen T, Kaprio J, et al. Associations of physical activity, fitness, and body composition with heart rate variability-based indicators of stress and recovery on workdays: A cross-sectional study. *J Occup Med Toxicol* 2014;9:16. doi:10.1186/1745-6673-9-16
17. Ross RM, Jackson AS. Exercise concepts, calculations, and computer applications. Carmel, Indiana: Benchmark press; 1990.
18. Firstbeat Technologies Ltd. EPOC based training effect assessment [White paper]. Published Sep 2005, updated March 2012. Available from: http://www.firstbeat.com/userData/firstbeat/download/white_paper_training_effect.pdf

19. Saalasti S. Neural networks for heart rate time series analysis [dissertation]. Jyväskylä, Finland: University of Jyväskylä; 2003. Available from: https://jyx.jyu.fi/dspace/bitstream/handle/123456789/13267/951391707X.pdf?sequence=1

20. Kettunen J, Saalasti S, inventors; Firstbeat Technologies Ltd , assignee. Procedure for deriving reliable information on respiratory activity from heart period measurement. United States patent US 7,460,901 B2. 2008 Dec 2. Available from: http://worldwide.espacenet.com/publicationDetails/originalDocument?CC=US&NR=7460901B2&KC=B2&FT=D&ND=4&date=20081202&DB=EPODOC&locale=fi_FI

21. Kettunen J, Saalasti S, inventors; Firstbeat Technologies Ltd , assignee. Procedure for detection of stress by segmentation and analyzing heart beat signal. United States patent US 7,330,752 B2. 2008 Feb 12. Available from: http://worldwide.espacenet.com/publicationDetails/originalDocument?FT=D&date=20080212&DB=EPODOC&locale=fi_FI&CC=US&NR=7330752B2&KC=B2&ND=4

22. Firstbeat Technologies Ltd. VO_2 estimation method based on heart rate measurement [White paper]. Published Feb 2005, updated March 2012. Available from: http://www.firstbeat.com/userData/firstbeat/download/white_paper_vo2_estimation.pdf

23. Kang M, Bassett DR, Barreira TV, Tudor-Locke C, Ainsworth B, Reis JP, et al. How many days are enough? A study of 365 days of pedometer monitoring. *Res Q Exerc Sport* 2009;80:445-53.

24. Troiano RP, Berrigan D, Dodd KW, Mâsse LC, Tilert T, McDowell M. Physical activity in the United States measured by accelerometer. *Med Sci Sports Exerc* 2008;40:181-8.

25. Hu FB, Willett WC, Li T, Stampfer MJ, Colditz GA, Manson JE. Adiposity as compared with physical activity in predicting mortality among women. *N Engl J Med* 2004;351:2694-703.

26. Pietiläinen KH, Kaprio J, Borg P, Plasqui G, Yki-Järvinen H, Kujala UM, et al. Physical inactivity and obesity: A vicious circle. *Obesity* 2008;16:409-14.

27. Strath SJ, Kaminsky LA, Ainsworth BE, Ekelund U, Freedson PS, Gary RA, et al. Guide to the assessment of physical activity: Clinical and research applications: A scientific statement from the American Heart Association. *Circulation* 2013;128:2259-79.

Table 1 Distributions of participants into moderate-to-vigorous and vigorous physical activity categories according to mean minutes per day on workdays and days off

	Workdays				Days off			
	0 min n (%)	>0-15 min n (%)	>15-30 min n (%)	>30 min n (%)	0 min n (%)	>0-15 min n (%)	>15-30 min n (%)	>30 min n (%)
Men (n=4221)								
$MVPA_{1min}$	91 (2.2)	835 (19.8)	706 (16.7)	2589 (61.3)	160 (3.8)	851 (20.2)	563 (13.3)	2647 (62.7)
$MVPA_{10min}$	1345 (31.9)	712 (16.9)	802 (19.0)	1362 (32.3)	1535 (36.4)	452 (10.7)	500 (11.8)	1734 (41.1)
VPA_{1min}	1544 (36.6)	1571 (37.2)	658 (15.6)	448 (10.6)	1862 (44.1)	1221 (28.9)	391 (9.3)	747 (17.7)
VPA_{10min}	3014 (71.4)	524 (12.4)	441 (10.4)	242 (5.7)	3189 (75.6)	236 (5.6)	292 (6.9)	504 (11.9)
Women (n=5333)								
$MVPA_{1min}$	480 (9.0)	1632 (30.6)	1015 (19.0)	2206 (41.4)	838 (15.7)	1612 (30.2)	760 (14.3)	2123 (39.8)
$MVPA_{10min}$	2523 (47.3)	913 (17.1)	864 (16.2)	1033 (19.4)	2999 (56.2)	469 (8.8)	550 (10.3)	1315 (24.7)
VPA_{1min}	3200 (60.0)	1454 (27.3)	440 (8.3)	239 (4.5)	3651 (68.5)	979 (18.4)	299 (5.6)	404 (7.6)
VPA_{10min}	4520 (84.8)	408 (7.7)	294 (5.5)	111 (2.1)	4690 (87.9)	196 (3.7)	169 (3.2)	278 (5.2)

$MVPA_{1min}$=moderate-to-vigorous physical activity (≥3 metabolic equivalents [METs]) calculated from single 1-minute bouts throughout the measurement period

$MVPA_{10min}$= moderate-to-vigorous physical activity (≥3 METs) calculated from bouts of physical activity lasting continuously for ≥10 minutes

VPA_{1min}=vigorous physical activity (≥6 METs) calculated from single 1-minute bouts throughout the measurement period

VPA_{10min}=vigorous physical activity (≥6 METs) calculated from bouts of physical activity lasting continuously for ≥10 minutes

Table 2 Amount of moderate-to-vigorous and vigorous physical activity during workdays and days off based on age group

	n (men/women)		Men Workdays (min/day)	Men Days off (min/day)	Men P*	Women Workdays (min/day)	Women Days off (min/day)	Women P*
$MVPA_{1min}$								
18-30 yrs	366/457	mean (SD)	88.6 (72.8)†	88.3 (75.7)†	0.81	76.6 (53.5)†	71.5 (61.9)†	0.005
		median	67.5†	69.0†		69.0†	60.0†	
31-40 yrs	1109/1251	mean (SD)	55.7 (44.2)†	67.7 (63.2)†	<0.001	42.1 (38.5)†	40.8 (40.6)†	0.041
		median	47.0†	52.3†		34.0†	28.0†	
41-50 yrs	1411/1905	mean (SD)	47.1 (42.5)†	59.9 (56.5)†	<0.001	28.3 (29.1)†	31.1 (37.1)†	0.34
		median	36.5†	47.0†		21.0†	17.0†	
51-65 yrs	1335/1720	mean (SD)	42.9 (46.2)†	53.3 (56.0)†	<0.001	20.5 (24.4)†	22.7 (33.3)†	0.74
		median	31.0†	37.5†		11.0†	8.0†	
VPA_{1min}								
18-30 yrs	366/457	mean (SD)	17.0 (21.4)†	17.6 (25.3)†	0.73	16.5 (19.9)†	15.1 (23.1)†	0.004
		median	10.0†	5.0†		9.0†	4.0†	
31-40 yrs	1109/1251	mean (SD)	11.6 (16.6)†	15.9 (24.4)†	<0.001	7.8 (12.7)†	8.1 (15.9)†	0.16
		median	4.0†	3.0†		1.0†	0.0†	
41-50 yrs	1411/1905	mean (SD)	9.9 (14.7)†	13.9 (24.9)†	<0.001	4.0 (9.1)†	5.8 (14.9)†	0.008
		median	2.0†	1.0†		0.0†	0.0†	
51-65 yrs	1335/1720	mean (SD)	7.4 (13.9)†	10.2 (21.2)†	0.003	1.8 (6.3)†	2.5 (11.2)†	0.54
		median	0.5†	0.0†		0.0†	0.0†	

* For the difference between workdays and days off by Wilcoxon two-sample paired signed rank test

† P<0.001 for the difference between age groups by Kruskal-Wallis test

$MVPA_{1min}$=moderate-to-vigorous physical activity (≥3 metabolic equivalents [METs]) calculated from single 1-minute bouts throughout the measurement period

VPA_{1min}=vigorous physical activity (≥6 METs) calculated from single 1-minute bouts throughout the measurement period

Table 3 Amount of moderate-to-vigorous and vigorous physical activity during workdays and days off based on weight status

	n (men/women)		Men Workdays (min/day)	Men Days off (min/day)	Men P*	Women Workdays (min/day)	Women Days off (min/day)	Women P*
$MVPA_{1min}$								
Normal weight	1495/2792	mean (SD)	60.1 (53.5)†	74.0 (67.4)†	<0.001	44.5 (39.6)†	46.4 (46.7)†	0.99
		median	48.0†	58.5†		35.5†	35.0†	
Overweight	2067/1627	mean (SD)	49.4 (46.2)†	60.0 (56.4)†	<0.001	24.5 (30.1)†	25.2 (33.0)†	0.60
		median	38.0†	46.0†		16.0†	12.0†	
Obese	659/914	mean (SD)	39.6 (43.5)†	42.9 (52.0)†	0.18	13.9 (21.3)†	12.6 (21.8)†	0.001
		median	29.0†	26.0†		4.8†	2.0†	
VPA_{1min}								
Normal weight	1495/2792	mean (SD)	13.2 (17.3)†	18.2 (27.4)†	<0.001	8.4 (13.8)†	10.0 (19.2)†	0.65
		median	5.5†	4.0†		1.0†	0.0†	
Overweight	2067/1627	mean (SD)	9.6 (15.5)†	12.6 (22.3)†	<0.001	2.5 (7.9)†	2.6 (9.1)†	0.44
		median	1.5†	1.0†		0.0†	0.0†	
Obese	659/914	mean (SD)	5.0 (11.3)†	6.1 (16.3)†	0.97	0.6 (3.1)†	0.5 (3.5)†	0.07
		median	0.0†	0.0†		0.0†	0.0†	

Normal weight=18.5 to <25.0 kg/m^2; overweight=25.0 to <30.0 kg/m^2; obese=30.0 to 40.0 kg/m^2

* For the difference between workdays and days off by Wilcoxon two-sample paired signed rank test

† P<0.001 for the difference between body mass index groups by Kruskal-Wallis test

$MVPA_{1min}$=moderate-to-vigorous physical activity (≥3 metabolic equivalents [METs]) calculated from single 1-minute bouts throughout the measurement period

VPA_{1min}=vigorous physical activity (≥6 METs) calculated from single 1-minute bouts throughout the measurement period

Table 4 Predictors of the amount of moderate-to-vigorous and vigorous physical activity

	$MVPA_{1min}$		VPA_{1min}	
	Coefficient (95% CI)	**P**	**Coefficient (95% CI)**	**P**
Age (18 yrs=0)	-1.130 (-1.203 to -1.056)	<0.001	-0.286 (-0.310 to -0.261)	<0.001
Gender (1=men; 0=women)	24.352 (22.930 to 25.773)	<0.001	6.584 (6.114 to 7.054)	<0.001
Body mass index (18.5 kg/m^2=0)	-2.464 (-2.639 to -2.288)	<0.001	-0.762 (-0.820 to -0.704)	<0.001
Type of day (1=workday; 0=day off)	-5.161 (-6.051 to -4.271)	<0.001	-1.934 (-2.312 to -1.556)	<0.001

$MVPA_{1min}$=moderate-to-vigorous physical activity (≥3 metabolic equivalents [METs]) calculated from single 1-minute bouts throughout the measurement period

VPA_{1min}=vigorous physical activity (≥6 METs) calculated from single 1-minute bouts throughout the measurement period

The dependent variables in the linear mixed effects regression models were $MVPA_{1min}$ and VPA_{1min} (minutes/day) as continuous variables.

Table 5 Probability of having a bout of moderate-to-vigorous or vigorous physical activity (per measurement day) lasting continuously for ≥10 minutes

	MVPA		VPA	
	Coefficient (95% CI)	**P**	**Coefficient (95% CI)**	**P**
Simple models				
Age (18 yrs=0)	-0.040 (-0.043 to -0.036)	<0.001	-0.047 (-0.052 to -0.042)	<0.001
Gender (1=men; 0=women)	0.948 (0.881 to 1.016)	<0.001	1.263 (1.163 to 1.363)	<0.001
Body mass index (18.5 kg/m^2=0)	-0.139 (-0.148 to -0.130)	<0.001	-0.186 (-0.202 to -0.171)	<0.001
Type of day (1=workday; 0=day off)	-0.189 (-0.242 to -0.135)	<0.001	-0.244 (-0.322 to -0.167)	<0.001
Interaction models				
Age (18 yrs=0)	-0.023 (-0.031 to -0.014)	<0.001	-0.032 (-0.043 to -0.021)	<0.001
Gender (1=men; 0=women)	-0.157 (-0.400 to 0.086)	0.21	-0.764 (-1.100 to -0.427)	<0.001
Body mass index (18.5 kg/m^2=0)	-0.078 (-0.107 to -0.050)	<0.001	-0.126 (-0.170 to -0.081)	<0.001
Type of day (1=workday; 0=day off)	0.135 (-0.049 to 0.319)	0.15	0.004 (-0.231 to 0.240)	0.97
Age*Body mass index	-0.003 (-0.004 to -0.002)	<0.001	-0.006 (-0.008 to -0.004)	<0.001
Gender*Age	0.030 (0.022 to 0.037)	<0.001	0.058 (0.047 to 0.068)	<0.001
Gender*Body mass index	0.068 (0.050 to 0.086)	<0.001	0.116 (0.085 to 0.147)	<0.001
Type of day*Age	-0.009 (-0.015 to -0.004)	0.001	-0.016 (-0.024 to -0.008)	<0.001
Type of day*Gender	-0.349 (-0.460 to -0.238)	<0.001	-0.188 (-0.364 to -0.013)	0.035
Type of day*Body mass index	0.012 (-0.003 to 0.027)	0.12	0.040 (0.013 to 0.066)	0.003

MVPA=moderate-to-vigorous physical activity (≥3 metabolic equivalents [METs]); VPA=vigorous physical activity (≥6 METs)

The results are from the generalized linear mixed effects regression models in which the dependent variables are binary outcomes (participant did or did not have a bout of moderate-to-vigorous or vigorous physical activity lasting ≥10 minutes).

Table 6 Proportion of participants fulfilling the physical activity recommendation* based on gender and weight status

	Men	Women
	% (95% CI)	**% (95% CI)**
$MVPA_{1min}$		
All	80.0 (78.8 to 81.2)	56.1 (54.7 to 57.4)
Normal weight	88.6 (86.8 to 90.1)	74.1 (72.4 to 75.7)
Overweight	79.4 (77.6 to 81.1)	43.8 (41.3 to 46.2)
Obese	62.5 (58.7 to 66.2)	23.0 (20.3 to 25.8)
$MVPA_{10min}$		
All	54.3 (52.8 to 55.8)	32.8 (31.6 to 34.1)
Normal weight	64.9 (62.4 to 67.3)	46.5 (44.6 to 48.3)
Overweight	52.7 (50.5 to 54.9)	22.1 (20.1 to 24.2)
Obese	35.5 (31.9 to 39.3)	10.3 (8.4 to 12.4)

* Moderate intensity physical activity at least 150 minutes per week, vigorous physical activity at least 75 minutes per week, or a combination of these (for details of calculation, see methods).

Normal weight=18.5 to <25.0 kg/m^2; overweight=25.0 to <30.0 kg/m^2; obese=30.0 to 40.0 kg/m^2

$MVPA_{1min}$= moderate-to-vigorous physical activity (≥3 metabolic equivalents [METs]) calculated from single 1-minute bouts throughout the measurement period

$MVPA_{10min}$= moderate-to-vigorous physical activity (≥3 METs) calculated from bouts of physical activity lasting continuously for ≥10 minutes

Figure legends

Figure 1 Flow of participants and measurement days included in the analysis.

Figure 2 The mean amount of moderate-to-vigorous physical activity (≥3 metabolic equivalents [METs]) (whole column) and its distribution into moderate (MPA; 3 to <6 METs) and vigorous (VPA; ≥6 METs) physical activity during workdays (WD) and days off (DO) by age among men and women. The 1 min notation indicates values for single 1-minute bouts throughout the measurement period, whereas the 10 min notation indicates values for bouts of physical activity lasting continuously for ≥10 minutes. P_3 and P_6 denote the differences between WD and DO in moderate-to-vigorous and vigorous physical activities, respectively. *physical activity was greater during WD than DO. Note the different scales between the upper and lower figures.

Figure 3 The mean amount of moderate-to-vigorous physical activity (≥3 metabolic equivalents [METs]) (whole column) and its distribution into moderate (MPA; 3 to <6 METs) and vigorous (VPA; ≥6 METs) physical activity during workdays (WD) and days off (DO) by weight status among men and women. Normal weight=18.5 to <25.0 kg/m^2; overweight=25.0 to <30.0 kg/m^2; obese=30.0 to 40.0 kg/m^2. The 1 min notation indicates values for single 1-minute bouts throughout the measurement period, whereas the 10 min notation indicates values for bouts of physical activity lasting continuously for ≥10 minutes. P_3 and P_6 denote the differences between WD and DO in moderate-to-vigorous and vigorous physical activities, respectively. *physical activity was greater during WD than DO. Note the different scales between the upper and lower figures.

Figure 4 Hourly distributions of moderate-to-vigorous (MVPA; ≥3 metabolic equivalents [METs]) and vigorous (VPA; ≥6 METs) physical activity by gender and weight status during workdays and days off. The mean number of minutes at a certain hour (e.g., 9 am) denotes

the number of minutes during the hour beginning from that time point (e.g., 9-10 am). Normal weight=18.5 to <25.0 kg/m^2; overweight=25.0 to <30.0 kg/m^2; obese=30.0 to 40.0 kg/m^2. The 1 min notation indicates values for single 1-minute bouts throughout the measurement period.

Figure 5 The proportion of participants fulfilling the physical activity recommendation (moderate intensity physical activity for at least 150 minutes per week, vigorous physical activity at least 75 minutes per week, or a combination of these) based on gender and weight status. Normal weight=18.5 to <25.0 kg/m^2; overweight=25.0 to <30.0 kg/m^2; obese=30.0 to 40.0 kg/m^2. Note the different scales between the upper and lower figures.

Fig. 1

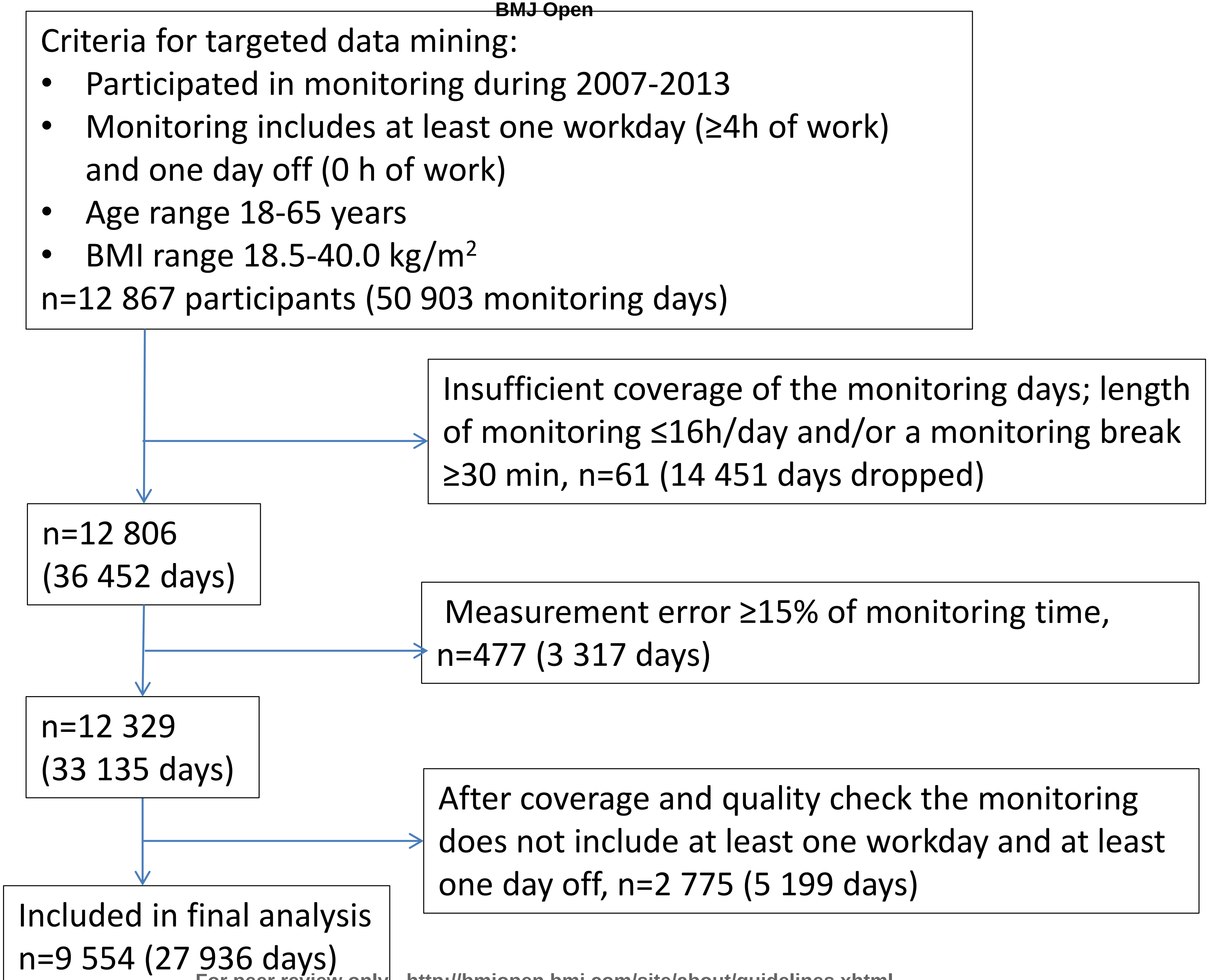

Criteria for targeted data mining:
• Participated in monitoring during 2007-2013
• Monitoring includes at least one workday (≥4h of work) and one day off (0 h of work)
• Age range 18-65 years
• BMI range 18.5-40.0 kg/m²
n=12 867 participants (50 903 monitoring days)
Insufficient coverage of the monitoring days; length of monitoring ≤16h/day and/or a monitoring break ≥30 min, n=61 (14 451 days dropped)
n=12 806 (36 452 days)
Measurement error ≥15% of monitoring time, n=477 (3 317 days)
n=12 329 (33 135 days)
After coverage and quality check the monitoring does not include at least one workday and at least one day off, n=2 775 (5 199 days)
Included in final analysis n=9 554 (27 936 days)

Fig 2

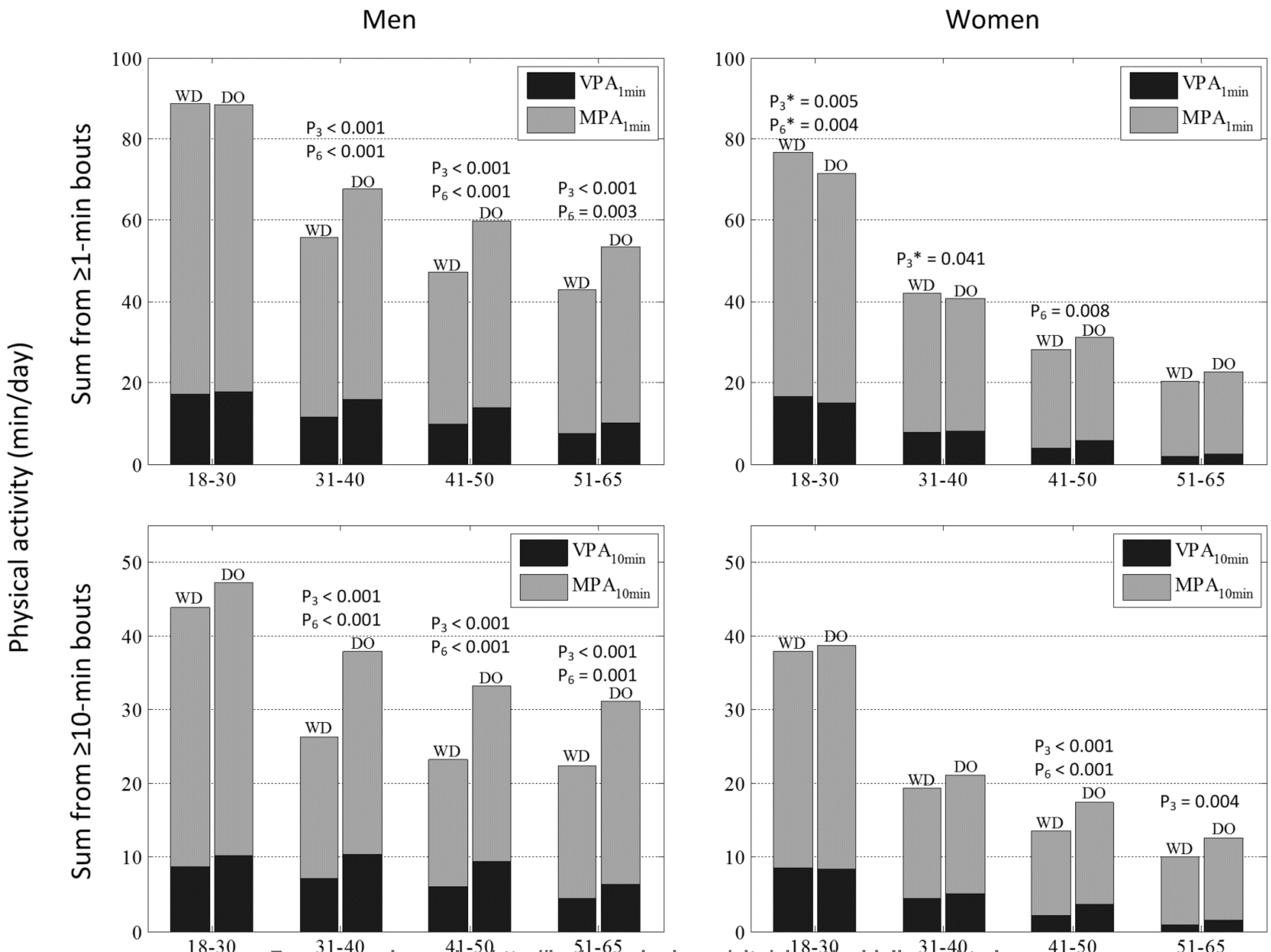

Men
Women
Physical activity (min/day)
Sum from ≥1-min bouts
Sum from ≥10-min bouts
VPA1min
MPA1min
VPA10min
MPA10min
WD
DO
P3 < 0.001
P6 < 0.001
P3 < 0.001
P6 = 0.003
P3* = 0.005
P6* = 0.004
P3* = 0.041
P6 = 0.008
P3 < 0.001
P6 = 0.001
P3 = 0.004
18-30
31-40
41-50
51-65

Fig 3

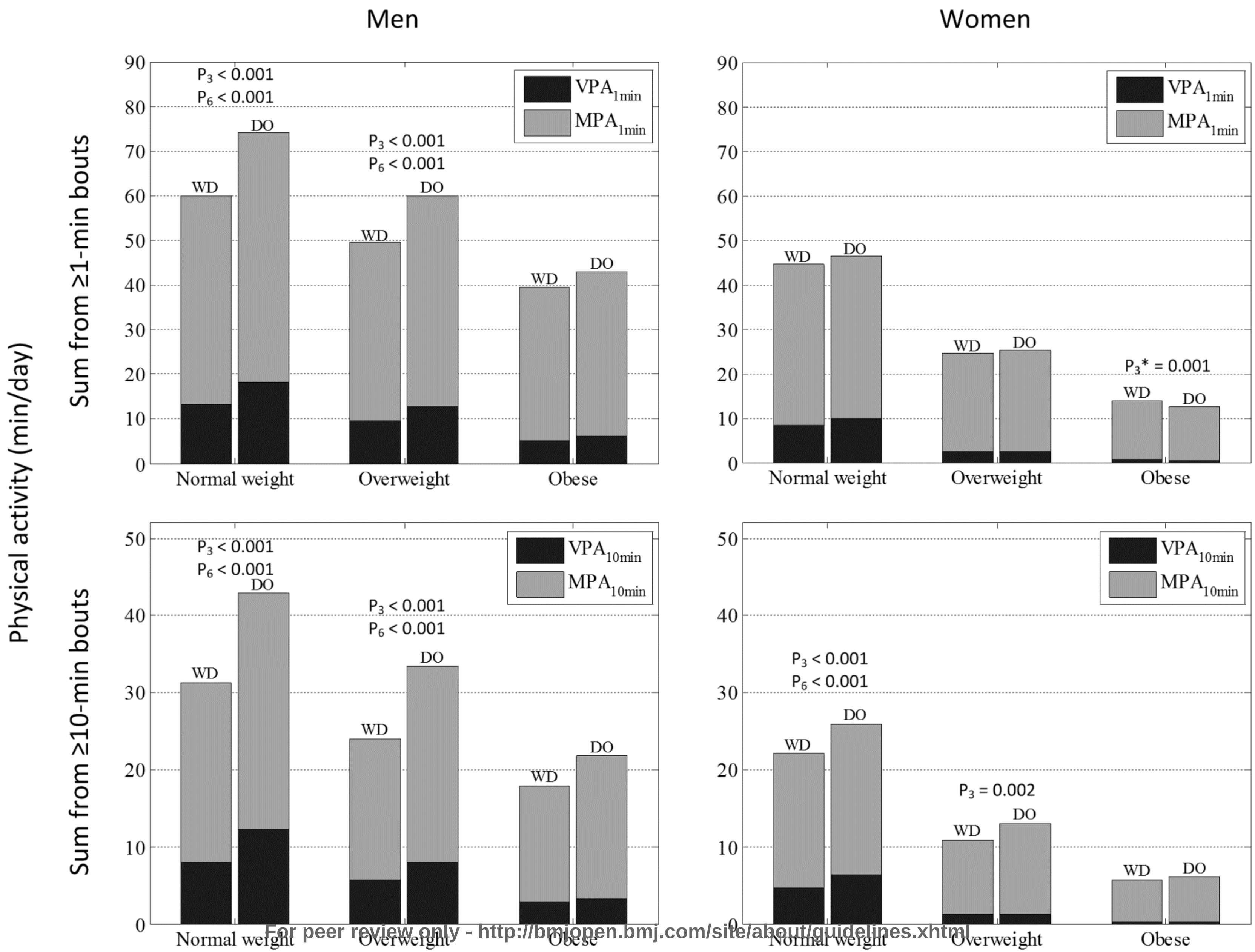

Men
Women
Physical activity (min/day)
Sum from ≥1-min bouts
Sum from ≥10-min bouts
VPA1min
MPA1min
VPA10min
MPA10min
P3 < 0.001
P6 < 0.001
P3* = 0.001
P3 = 0.002
WD
DO
Normal weight
Overweight
Obese

Fig 4

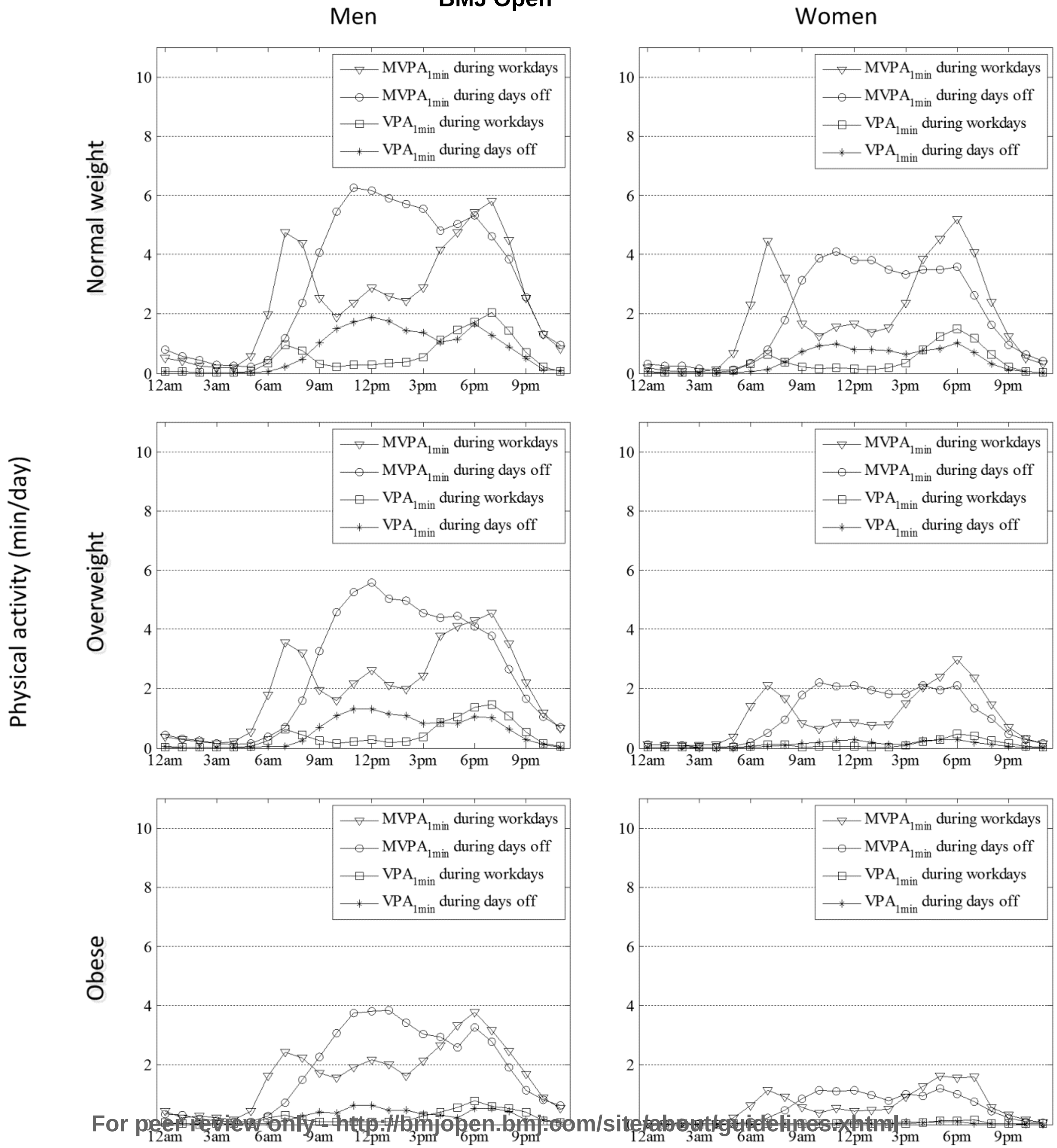
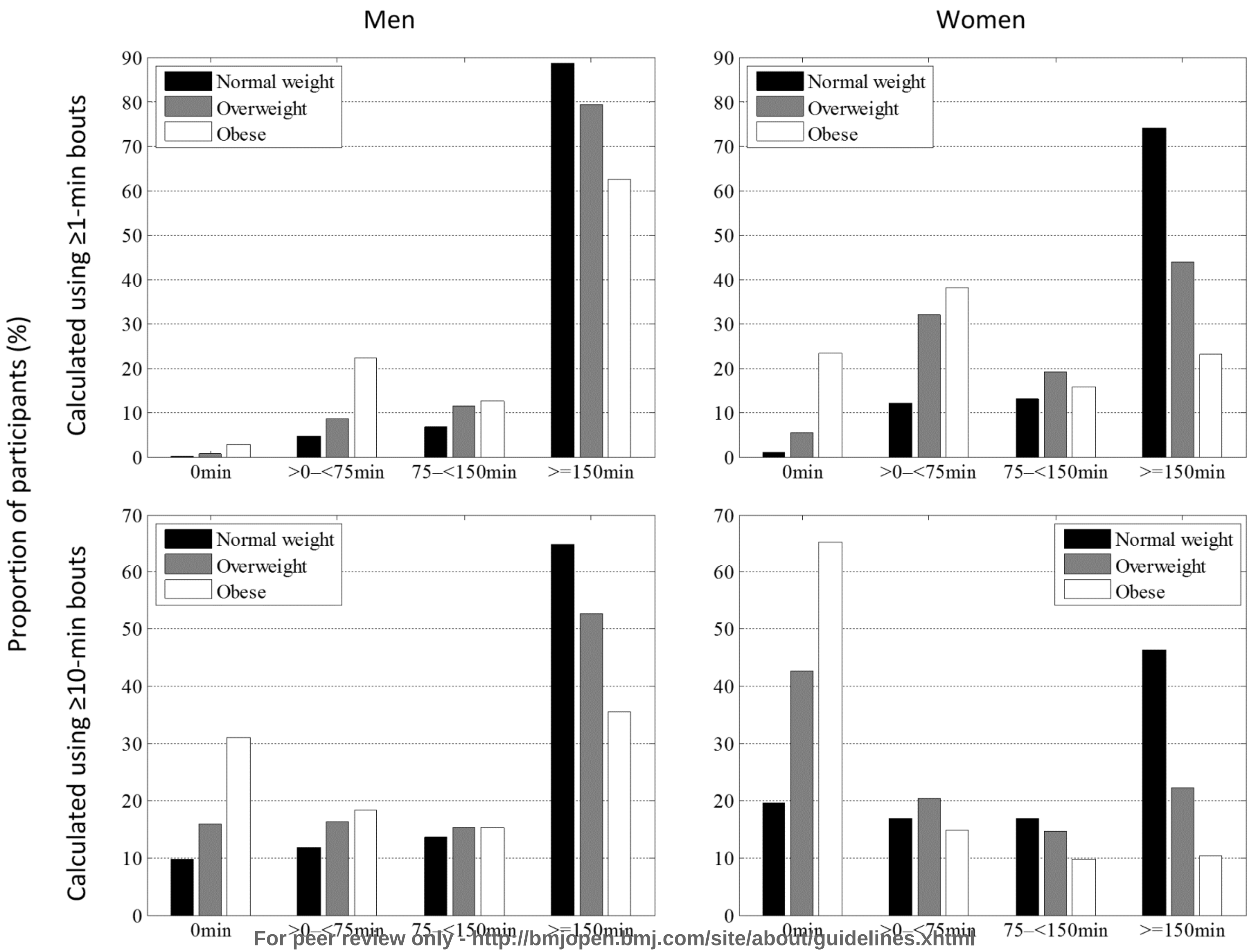

Men
Women
Physical activity (min/day)
Normal weight
Overweight
Obese
$MVPA_{1min}$ during workdays
$MVPA_{1min}$ during days off
VPA_{1min} during workdays
VPA_{1min} during days off
0
2
4
6
8
10
12am
3am
6am
9am
12pm
3pm
6pm
9pm

Fig 5



Men
Women
Proportion of participants (%)
Calculated using ≥1-min bouts
Calculated using ≥10-min bouts
Normal weight
Overweight
Obese
0min
>0–<75min
75–<150min
>=150min

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract SEE PAGES 1- 2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found SEE PAGES 1- 2
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported SEE PAGES 5-6
Objectives	3	State specific objectives, including any prespecified hypotheses SEE PAGE 6
Methods		
Study design	4	Present key elements of study design early in the paper SEE ABSTRACT AND PAGE 6-
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection SEE PAGE 6
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants SEE PAGES 6-7 AND FIGURE 1
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable DEFINED IN METHODS
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group DEFINED IN METHODS
Bias	9	Describe any efforts to address potential sources of bias WE HAVE ANALYZED THAT DIFFERENT STEPS IN DATA MINING SUCH AS FOCUSING ONLY TO THOSE WHO HAVE RECORDINGS FROM DAYS OFF AND WORKDAYS DO NOT CHANGE THE RESULTS. COMPLETE DISCUSSION ON ALL ANALYSES DONE FOR THIS PURPOSE COULD NOT BE INCLUDED IN THE PAPER, SHORT COMMENT IN DISCUSSION
Study size	10	Explain how the study size was arrived at AVAILABLE DATA FOR DATA MINING, VERY BIG DATASET, EXPLAINED IN METHODS
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why DEFINED IN METHODS
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding DEFINED IN STATISTICAL METHODS
		(*b*) Describe any methods used to examine subgroups and interactions DEFINED IN STATISTICAL METHODS
		(*c*) Explain how missing data were addressed EXPLAINED IN METHODS AND

		FLOW CHART
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy EXPLAINED IN METHODS
		(*e*) Describe any sensitivity analyses
Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed DEFINED IN METHODS AND FIGURE 1
		(b) Give reasons for non-participation at each stage DEFINED IN METHODS AND FIGURE 1
		(c) Consider use of a flow diagram SEE FIGURE 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders GIVEN IN METHODS AND THE BEGINNING OF RESULTS
		(b) Indicate number of participants with missing data for each variable of interest DEFINED IN METHODS AND FIGURE 1
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time
		Case-control study—Report numbers in each exposure category, or summary measures of exposure
		Cross-sectional study—Report numbers of outcome events or summary measures SEE TABLES
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included SEE ABSTRACT AND RESULTS
		(*b*) Report category boundaries when continuous variables were categorized REPORTED IN APPROPRIATE PLACES; METHODS, RESULTS, TABLES, FIGURES
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses SEE RESULTS
Discussion		
Key results	18	Summarise key results with reference to study objectives PAGES 14-15
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias PAGES 15-16
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence PAGES 14-15, DISCUSSION ELSEWHERE
Generalisability	21	Discuss the generalisability (external validity) of the study results PAGES 14-15, DISCUSSION ELSEWHERE
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based PAGE 20

BMJ Open

Objectively measured physical activity in Finnish employees: a cross-sectional study

Journal:	*BMJ Open*
Manuscript ID:	bmjopen-2014-005927.R1
Article Type:	Research
Date Submitted by the Author:	02-Oct-2014
Complete List of Authors:	Mutikainen, Sara; University of Jyvaskyla Helander, Elina; Tampere University of Technology, Department of Signal Processing Pietilä, Julia; Tampere University of Technology, Department of Signal Processing Korhonen, Ilkka; Tampere University of Technology, Department of Signal Processing Kujala, Urho; University of Jyväskylä, Department of Health Sciences
Primary Subject Heading:	Sports and exercise medicine
Secondary Subject Heading:	Public health, Occupational and environmental medicine, Rehabilitation medicine, Epidemiology
Keywords:	Physical activity, Obesity, Exercise intensity, Heart rate variability, Objective monitoring

Objectively measured physical activity in Finnish employees: a cross-sectional study

Sara Mutikainen, Elina Helander, Julia Pietilä, Ilkka Korhonen, Urho M. Kujala

Department of Health Sciences, University of Jyväskylä, Jyväskylä, Finland Sara Mutikainen post-doctoral researcher, Urho M Kujala professor

Department of Signal Processing, Tampere University of Technology, Tampere, Finland Elina Helander post-doctoral researcher, Julia Pietilä research assistant, Ilkka Korhonen professor

VTT Technical Research Center of Finland, Tampere, Finland Ilkka Korhonen professor

Correspondence to:

Urho M. Kujala, M.D., Ph.D., Department of Health Sciences, University of Jyväskylä, P.O.Box 35 (LL), FI-40014 University of Jyväskylä, Finland

Tel: +358408053567, Fax: +35814617423, E-mail: urho.m.kujala@jyu.fi

Abstract

Objectives To objectively measure the amount of intensity-specific physical activity by gender and age with respect to body mass index (BMI) during workdays and days off among Finnish employees.

Design A cross-sectional study.

Setting Primary care occupational health care units.

Participants A sample of 9554 Finnish employees (4221 men and 5333 women; age range 18-65 years; BMI range 18.5-40.0 kg/m^2) who participated in health assessments related to occupational health promotion.

Main outcome measurements The amount of moderate-to-vigorous (MVPA) and vigorous (VPA) physical activity (≥3 and ≥6 metabolic equivalents, respectively) was assessed by estimating minute-to-minute oxygen consumption from the recorded beat-to-beat R-R interval data. The estimation method used heart rate, respiration rate, and on/off response information from R-R interval data calibrated by age, gender, height, weight, and self-reported physical activity class. The proportion of participants fulfilling the aerobic physical activity recommendation of ≥150 minutes/week was calculated on the basis of ≥10-minute bouts, multiplying VPA minutes by 2.

Results Both MVPA and VPA were higher among men and during days off, and decreased with increasing age and BMI ($P<0.001$ for all). Similar results were observed when the probability of having a bout of MVPA or VPA lasting continuously for ≥10 minutes per measurement day was studied. The total amount of VPA was low among overweight (mean ≤2.6 minutes/day), obese (mean ≤0.6 minutes/day), and all 51 to 65-year-old (mean ≤2.5 minutes/day) women during both types of days. The proportion of participants fulfilling the aerobic physical activity recommendation was highest for normal weight men (65%; 95% CI 62 to 67%) and lowest for obese women (10%; 95% CI 8 to 12%).

Conclusions Objectively measured physical activity is higher among men and during days off and decreases with increasing age and BMI. The amount of VPA is very low among obese, overweight, and older women.

Strengths and limitations of this study

- Using novel validated methodology, our study provides accurate data on intensity-specific physical activity in a large sample of working age individuals, with detailed associations between intensity-specific physical activity and gender, age, body mass index, and the type of day (workday vs. day off) and their interactions.
- The study sample was not a random sample from the population, but a 'real life' clinical sample of employees who participated in preventive occupational health care.
- Our recordings usually covered some typical workdays and days off, a longer recording may be more valid than the duration used in our study.

Introduction

Epidemiological evidence, studies on underlying mechanisms, and intervention studies suggest that physical activity plays an important role in the prevention of body fat accumulation and type 2 diabetes.[1-5] Observational studies suggest that physical activity may also have other health benefits such as reduced risk for cardiovascular disease,[6-8] dementia,[8] depression [9] and mortality.[10] To achieve these health benefits, according to recent recommendations, moderate intensity aerobic physical activity should be performed for at least 150 minutes or vigorous physical activity at least 75 minutes per week.[3 11 12] However, accurately recording the amount and intensity of physical activity with regard to both physical activity-related energy requirements and cardio-respiratory loading is challenging.[13 14] Objective information is usually obtained by heart rate (HR) monitors or motion sensors, such as accelerometers.[15] Existing data suggest that, among obese individuals, the amount of vigorous physical activity is low compared to current recommendations.[14 16-18] However, estimating the cardio-respiratory loading of physical activity among obese and/or unfit individuals is difficult using accelerometers or other motion sensors.

HR monitoring is a common method of assessing the intensity of physical activity in clinical settings. HR is almost linearly associated with oxygen consumption (VO_2) at moderate to submaximal intensities in steady-state exercise; therefore, it can be used to estimate the intensity of steady-state physical activity. However, the intensity of real life physical activity usually changes repeatedly, and the relationship between HR and VO_2 is curvilinear for very low intensity physical activities and near maximal exercise; thus, the actual VO_2 can be over- or underestimated when using the linear HR-VO_2 relationship to estimate the actual VO_2.[19] Continuous measurement of HR variability and experimental calibration of data by age, gender, weight, height, and self-reported physical activity class was recently shown to provide accurate estimates of the intensity of physical activity.[20] We used such novel methodology in this study to estimate the intensity of physical activity in a large sample of Finnish employees.

The aim of this study was to investigate the amount of physical activity among 9554 Finnish employees who had participated in continuous beat-to-beat R-R interval (ECG) recordings during the course of their normal everyday life. More specifically, we investigated the intensity-specific amount of physical activity by gender and age with respect to body mass index (BMI) during workdays vs. days off, including hourly distributions of physical activity throughout the day. This information is an important basis for understanding the cardio-respiratory loading caused by physical activity and the needs and realistic possibilities for interventions that increase physical activity.

Methods

Study design and participants

This study is a cross-sectional study investigating the intensity and amount of physical activity among a clinical sample of 9554 Finnish employees (4221 men and 5333 women; age range 18-65 years; BMI range 18.5-40.0 kg/m^2) who participated in preventive occupational health care provided by their employers during the years 2007-2013 (Figure 1). The participants non-selectively represent a wide range of non-manual and manual labor employees and, thus, a cross-section of typical Finnish employees. As a part of these health care programs, participants performed continuous beat-to-beat R-R interval recordings in the course of their normal everyday life as described below. The clinical purpose of these recordings was to assess the intensity and amount of physical activity (reported in this paper) and other R-R interval -derived information such as the amount of stress and recovery [21] (not reported in this paper) during workdays and days off. To acquire these so-called Lifestyle

Assessment results, the R-R interval data were analyzed using Firstbeat Analysis Server software (Firstbeat Technologies Ltd, Jyväskylä, Finland). On the basis of the results, the participants received personal feedback and recommendations for maintaining or improving their health and wellbeing.

The majority of the participants in this study were apparently healthy. The exclusion criteria for participation in the R-R interval recordings represented by the analysis software manufacturer were: chronic rhythm disturbance, cardiac pacemaker or transplant, left bundle branch block, severe cardiac disease (e.g., symptomatic coronary heart disease, heart failure), very high blood pressure (≥180/100 mmHg), type 1 or 2 diabetes with autonomic neuropathy, hyperthyreosis or other disturbances of the thyroid gland leading to a resting HR >80 bpm, severe neurological disease (e.g., advanced multiple sclerosis or Parkinson's disease), fever or other acute disease, and BMI >40.0 kg/m^2. Cases of milder/early disease stages and some medications may affect R-R intervals or physical activity levels. The inclusion/exclusion of these participants from the R-R interval recordings was evaluated on a case-by-case basis in the occupational health care programs.

The data obtained from these R-R interval recordings were analyzed and anonymously stored in a database administered by the software manufacturer (Firstbeat Technologies Ltd). Firstbeat Technologies Ltd and each service provider (e.g., occupational health care unit) who conducted the recordings for employees (participants) signed an agreement providing Firstbeat Technologies Ltd the right to store the data in an anonymized form and to use it for development and research purposes with a statement that employers must inform their employees about its use. According to the agreement, Firstbeat Technologies Ltd extracted an anonymous data file from the registry for the present research purposes.

Physical activity assessment

The ambulatory beat-to-beat R-R interval data used to calculate the intensity and amount of physical activity were recorded during the course of normal everyday life, usually over three days (typically including two workdays and one day off), using the Firstbeat Bodyguard device (Firstbeat Technologies Ltd). Data from the measurements were analyzed using Firstbeat Analysis Server software (version 5.6.0.3, Firstbeat Technologies Ltd). To be included in the analyses (Figure 1), a participant had to have a measurement period including at least one workday and one day off. We included a workday or a day off in the analysis if the measurement period lasted >16 hours/day. The information about workdays and days off was obtained from the diaries the participants were asked to fill in during the measurement period. A day was considered to be a workday if a participant worked ≥4 hours cumulatively. The days without any working hours were regarded as days off and the days with work time < 4 hours were excluded from the analyses. The analyzed data consisted of successfully recorded (measurement error <15% and <30 minute recording break) workdays and days off (Figure 1). The Firstbeat Bodyguard device cannot be used during swimming. Since we accepted only measurement days with <30 minute recording breaks, the days with longer watersports sessions (≥30 minutes) are excluded from our analyses.

Background information included age, gender, self-reported height and weight, and self-reported physical activity class[22] modified from Ross and Jackson.[23] This information was collected in conjunction with R-R interval recordings using questionnaires. Background information was used to estimate maximal HR[24] and maximal $VO_{2,}$[25] which were used in the estimation of VO_2. If a period with HR higher than the estimated was found from the recording, the maximal HR used for further calculations was corrected accordingly. For the statistical analyses, BMI was calculated from the self-reported weight and height as kilograms per meters squared.

The intensity and amount of physical activity was estimated based on the R-R interval recordings.[26-29] The method was validated previously; the pooled relationship (correlation) between the measured and predicted VO_2 across the different activities of daily living was 0.93 and the estimated VO_2 explained 87% of the variability in the measured VO_2.[20] The high validity of this method was achieved by taking into account the R-R interval-derived information about HR, respiration rate, and on/off response (increasing or decreasing HR) using neural network modeling of the data and short time Fourier Transform method.[26-29]

The participant's mean VO_2 for each minute during each measurement day was calculated from the second-by-second VO_2 estimations. The minute-by-minute VO_2 estimations were then converted to multiples of the resting metabolic rate (METs) by dividing the VO_2 values by 3.5. Based on the MET values, the amount of physical activity (minutes/day) at a certain intensity level was calculated two ways. First, we searched the recordings for single 1-minute segments in which the intensity reached the following MET thresholds: moderate physical activity (MPA) 3 to <6 METs, vigorous physical activity (VPA) ≥6 METs, and moderate-to-vigorous physical activity (MVPA) ≥3 METs,[12] which are referred to as MPA_{1min}, VPA_{1min}, and $MVPA_{1min}$ later in the text. The total number of 1-minute segments above the given thresholds during each measurement day was then calculated. These calculations were performed separately for workdays and days off. If a participant's measurement period included two or more workdays (or days off), an average was calculated. Second, because the recommendation for health-enhancing physical activity suggests that the duration of a bout of aerobic activity should be 10 continuous minutes or longer,[3 11 12] we utilized this in our calculations for different intensity categories, which are referred to as MPA_{10min}, VPA_{10min}, and $MVPA_{10min}$ later in the text. In this case, we calculated the total number of 1-minute segments above the given intensity thresholds during each measurement day using only the bouts of physical activity that lasted continuously for ≥10 minutes. The consecutive 1-minute segments had to be above the given intensity thresholds for at least 10 minutes, except for one 1-minute segment, which was allowed to be less than the given threshold. Otherwise the calculations were performed using the same principles as described above for single 1-minute segments.

Analysis

Data processing and statistical analysis were performed using MATLAB version R2013b (The MathWorks Inc., Natick, Massachusetts, U.S.A.) and R version 3.0.2 (The R Foundation for Statistical Computing, Vienna, Austria). All P values were two-sided and $P<0.05$ was considered statistically significant.

We calculated means, standard deviations, and medians for continuous variables and frequencies and proportions for categorical variables. We categorized the amount of MVPA and VPA into four categories (0, >0 to 15, >15 to 30 and >30 min) and calculated the distribution of participants in these categories by gender and type of day (i.e., workdays vs. days off). We also calculated the amount of MVPA and VPA by gender and type of day for different age categories (18-30, 31-40, 41-50, and 51-65 years) and BMI categories (normal weight 18.5 to <25.0 kg/m^2, overweight 25.0 to <30.0 kg/m^2, and obese 30.0 to 40.0 kg/m^2). The amount of MVPA and VPA during the workdays and days off were compared by gender inside each age and BMI category using the Wilcoxon two-sample paired signed rank test. The test assessed whether the differences in the amount of MVPA and VPA between each participant's workdays and days off came from a distribution with a median of zero. Differences in the amount of MVPA and VPA between age categories and between BMI categories were analyzed using the Kruskal-Wallis test. To describe the temporal distribution of physical activity, we calculated the amount of MVPA and VPA in each hour (e.g., from 9 am to 10 am, from 10 am to 11 am, etc.) during the day by gender, BMI category, and type of day. For illustrative reasons, the means are shown in all figures instead of medians.

The probability of having at least one 10-minute bout of MVPA or VPA per measurement day (binary outcome; yes vs. no) was modeled using a generalized linear mixed effects regression (procedure *glmer* with Laplace approximation in R). Each participant was incorporated as a random effect, and fixed effects included age and BMI as continuous variables and gender and type of day as binary variables. In the modeling, we also included all of the possible two-way interactions among these four variables. We also used linear mixed effects regression (procedure *fitlme* with maximum likelihood estimation in MATLAB) to predict the amount of $MVPA_{1min}$ and VPA_{1min}. In this case, each participant was incorporated as a random effect and fixed effects included age, BMI, gender, and type of day. The baselines for age (minimum 18) and BMI (minimum 18.5) were subtracted from age and BMI data, respectively, before regression calculations.

We also investigated how participants fulfill the aerobic physical activity recommendations of moderate intensity physical activity at least 150 minutes per week or vigorous physical activity at least 75 minutes per week as measured from ≥10-minute bouts of activity.[3] First, we calculated the activity minutes score for each day (MPA minutes + VPA minutes x 2) and then extrapolated the amount of physical activity using the following formula: Weekly physical activity = (5 x mean workday activity score) + (2 x mean day off activity score). This calculation was performed with only the bouts of physical activity lasting continuously for ≥10 minutes as recommended,[3] and then with all ≥1-minute bouts.

Results

Most of the R-R-interval recordings were from three days (7685 participants); there were 1394, 319, 119, and 37 participants who had two, four, five, and six measurement days, respectively. Altogether, the number of analyzed days was 17020 for workdays and 10916 for days off. The mean (SD) age of the participants was 44.8 (9.7) years [men 44.7 (9.7); women 44.9 (9.7)] and the mean (SD) BMI was 26.1 (4.1) kg/m^2 [men 26.7 (3.5); women 25.7 (4.4)].

Table 1 shows the distributions of participants into the MVPA and VPA categories by workdays and days off among the 4221 men and 5333 women who participated in this study. For more than 60% of men and approximately 40% of women, the amount of $MVPA_{1min}$ was more than 30 minutes per day, regardless of the type of day, whereas 11% (workdays) and 18% (days off) of men and 4% (workdays) and 8% (days off) of women had VPA_{1min} for more than 30 minutes per day. All these percentages were clearly lower for $MVPA_{10min}$ and VPA_{10min}.

Figure 2 and Table 2 show the amount of MVPA and VPA by age, gender, and the type of day. The amount of MVPA and VPA decreased with advancing age, especially among women. Among men aged 31 years and older, the amounts of $MVPA_{1min}$, $MVPA_{10min}$, VPA_{1min}, and VPA_{10min} were greater during days off than during workdays. Among younger women (18-40 years), the amount of $MVPA_{1min}$ was lower during days off compared to working days, whereas the amount of $MVPA_{10min}$ was higher during days off among older women (41-65 years). Other clear trends were not observed among women.

Figure 3 and Table 3 show the amount of MVPA and VPA by weight status, gender, and the type of day. Obese participants had less MVPA and VPA than normal weight and overweight participants, especially women. The mean amount of VPA_{1min} was approximately 0.5 minutes per day among obese women, for both workdays and days off. Among obese men, the mean amount of VPA_{1min} was 5.0 minutes during workdays and 6.1 minutes during days off. The mean amount of VPA_{1min} was also low among overweight women (~2.5 minutes per day for both workdays and days off). Among normal weight and overweight men, the amount of

$MVPA_{1min}$, $MVPA_{10min}$, VPA_{1min}, and VPA_{10min} were all greater during days off than workdays, but these differences were not observed among obese men. The corresponding results for women were more complex. Normal weight and overweight women had more $MVPA_{10min}$ during days off than during workdays. However, the amount of $MVPA_{1min}$ was similar between the types of days. On the other hand, obese women had a lower amount of $MVPA_{1min}$ during days off than workdays, but the amount of $MVPA_{10min}$ was similar between the types of day. Differences between workdays and days off with regard to VPA were observed for normal weight women; VPA_{10min} was higher during days off than workdays.

Hourly distributions of MVPA and VPA by gender, weight status, and type of day are shown in Figure 4. The largest amounts of MVPA during workdays occurred at 7-8 am and 5-7 pm. During days off, the largest amounts of MVPA were distributed evenly between 10 am and 6 pm. The respective VPA profiles resemble those of MVPA. During workdays, a small peak occurred at 7-8 am, but the greatest amount of VPA was clearly seen at 5-8 pm. The greatest amount of VPA during days off occurred between 10 am and 8 pm. For both genders, the amount of MVPA and VPA during workdays and days off decreased with increasing BMI.

When age, gender, BMI, and the type of day were included in the linear mixed effects regression models as predictors of the amount of $MVPA_{1min}$ or VPA_{1min} (Table 4), the predictors associated with both outcome measures in similar manners. The amount of $MVPA_{1min}$ and VPA_{1min} decreased with increasing age and increasing BMI. The amounts of $MVPA_{1min}$ and VPA_{1min} were higher among men compared to women and higher during days off than during workdays ($P<0.001$ for all). Similar results were observed when we studied the probability of having a bout of MVPA or VPA (per measurement day) that lasted continuously for ≥10 minutes (Table 5). The probability was higher among men and during days off, and it decreased with increasing age and increasing BMI ($P<0.001$ for all).

We also performed multivariate analysis for the probability of having a bout of MVPA or VPA lasting continuously for ≥10 minutes including two-way interactions between age, gender, BMI, and the type of day (Table 5). Many statistically significant interactions were observed between these variables. Both higher BMI and higher age decreased the likelihood of participating in MVPA or VPA, but BMI affected older participants more than younger participants. In addition, women were more affected by higher age or higher BMI than men. With increasing age, the probability of MVPA or VPA increased for days off compared to workdays. With increasing BMI, the probability of MVPA and VPA increased for workdays compared to days off.

The percentages of participants (by gender and weight status) who fulfilled the aerobic physical activity recommendations are provided in Figure 5 and Table 6. The proportion of participants fulfilling the recommendations decreased with increasing BMI for both men and women. The same was true when the weekly physical activity was calculated including all ≥1-minute bouts. Men fulfilled the recommendations better than women. The proportion fulfilling the recommendations was highest among normal weight men (64.9%, 95% CI 62.4 to 67.3 when ≥10-minute bouts were included in the calculation and 88.6%, 95% CI 86.8 to 90.1 when ≥1-minute bouts were included) and lowest among obese women (10.3%, 95% CI 8.4 to 12.4 and 23.0%, 95% CI 20.3 to 25.8, respectively).

Discussion

We found that the amount of physical activity decreases with increasing age and increasing BMI for both genders, but with a deeper decline among women. The amount of VPA was particularly low among older (51-65 years) and obese and overweight women. Men had more physical activity than women, and physical activity was more common during days off than during workdays, especially among men. The hourly distribution of physical activity clearly differed between workdays and days off. During workdays, physical activity was most common early in the morning and right after working hours, whereas physical activity was distributed more evenly throughout the day during days off. In addition, the proportion of participants fulfilling the aerobic physical activity recommendations decreased with increasing BMI and was lower for women than for men. Approximately one-third of the obese men and one-tenth of obese women fulfilled the aerobic physical activity recommendations.

Strengths and weaknesses of the study

Our study has several strengths. First, our study sample was very large and included a wide range of non-manual and manual labor employees although we did not have individual self-reported information on job titles available for the analysis in our data mining/register –type study. Second, we used a novel ambulatory beat-to-beat R-R interval-based method to assess the intensity of physical activity. This method has been shown to provide more accurate estimates of the intensity of physical activity than HR information only.[20 29] Third, we had strict criteria for the inclusion of recording days (e.g., measurement error <15% and recording break <30 minutes); thus, our recordings had good coverage of typical workdays and days off. Nonetheless, our study also has some weaknesses. Most of the participants were apparently healthy, but some participants with chronic diseases and/or medications that do not severely affect HR were also included in the sample of employees. We did not adjust for these conditions in the analysis since this information was not available for the analysis in our data mining/register –type study. In addition, the study sample was not a random sample from the population, but a ‘real life’ clinical sample of employees who participated in preventive occupational health care. This can be considered as either a strength or a weakness depending on the perspective. Our method for assessing physical activity can differentiate between the intensities of physical activity MET by MET, but to simplify our presentations, we used cut-off points of ≥3 and ≥6 METs to describe MVPA and VPA, respectively, as these are used in the physical activity recommendations.[12] The durations of our recordings were from two to six days and on the basis of these recordings, the amount of weekly physical activity was estimated in order to determine the proportion of participants who fulfill the aerobic physical activity recommendations. To accurately assess individual long-term physical activity levels, a longer recording is more valid than the duration used in our study.[30] Our recordings usually covered some typical workdays and days off, as our aim was to obtain recordings covering most of the day without artifacts. To achieve this goal, stick-on electrodes with wires were used for the collection of R-R interval data, but in some individuals, the electrodes cause skin irritation that make it difficult to make long recordings.

Findings in relation to other studies

The majority of previous studies including large study populations used accelerometers or pedometers for the objective assessment of physical activity. These methods provide rough estimates of the intensity of physical activity. We used beat-to-beat R-R interval data, which allows more accurate estimations of the intensity of physical activity, but it also has limitations when comparing our results to previous results. The age- and BMI-associated declines in the amount of physical activity observed in our study are in agreement with the results of the studies using accelerometers.[14 17 18 31] In our study, the amount of VPA was very low, especially among older women and overweight and obese women, and similar results have been reported in previous studies that used accelerometers.[14 17 31] Our results on the clear difference between workdays and days off in the hourly distribution of physical activity are in accordance with previous studies.[18] In addition, we observed that the proportions of overweight and obese participants fulfilling the aerobic physical activity recommendations are lower than the proportion of normal weight participants. Previous studies obtained similar results showing that among obese individuals especially the amount of VPA is low compared with the current recommendation.[14 16 18] Previous questionnaire-based studies in Finland have reported that approximately one-quarter[32] to one-half[33] of the working-aged adults (both men and women) fulfill the current aerobic physical activity recommendation. Our objectively measured results (men 54%, women 33%) covering both work-related and leisure physical activities are roughly in line with these results.

Overall, most of the associations in our study are similar to previous population-based studies that used accelerometers. However, our method measures cardio-respiratory loading more directly than the methods based on motion sensors. The amount of physical activity calculated from the bouts lasting ≥10 minutes should be used when determining who meets the current physical activity recommendations.[3] We calculated the amount of MVPA and VPA in two different ways that reflect different aspects of physical activity. The amount of physical activity calculated from single 1-minute bouts throughout the measurement period may be considered to reflect daily activities rather than fitness-enhancing exercise, as this method also takes into account very short bouts of physical activity, such as climbing stairs. Interestingly, the proportion of participants fulfilling the aerobic physical activity recommendation is doubled when shorter bouts are included in the calculation (Table 5).

Meaning of the study: implications for clinicians and policymakers

Increasing physical activity and reducing obesity are both important targets for improving overall population health, as both obesity and low physical activity are predictors of mortality.[34] According to our study approximately one-third of Finnish working-aged women and half of working-aged men meet the current recommendations for aerobic physical activity. The proportion is especially low among overweight and obese women and obese men. On the basis of this and our other observations, the amount of physical activity, especially the amount of VPA, seems to be very low among overweight and obese individuals, particularly women. As our study is cross-sectional in nature, it does not show the direction of causality between physical activity and obesity. However, this evidence shows the vicious cycle between obesity and physical inactivity.[35] The low number of obese individuals meeting the recommendations and their low starting level (with regard to total amount, duration, and intensity) should be taken into account when tailoring interventions for increasing physical activity. For obese individuals, the amount of MPA, or perhaps low intensity activity, should be increased first. Among obese individuals, objectively measured physical activity seems to be low both during leisure and at work. Thus, both leisure hours and working hours need attention when tailoring activity interventions. Overall, the documentation of physical activity levels as a part of routine health care should be improved.[36]

Unanswered questions and future research

In light of our findings, long-term controlled intervention studies are needed to show whether MPA or VPA as the main component of intervention programs has a better benefit-risk balance among obese individuals in terms of adherence, weight-control, morbidity, and mortality. Also, more detailed research is needed on whether short bouts of physical activity lead to long-term health benefits comparable to longer bouts at the disease-outcome level. Accurate methods of monitoring physical activity that cover cardio-respiratory loading are also needed to carry out large-scale studies on these topics and to analyze whether specific types of short-term activity provide health benefits. Notably, some physical activity is under the intensity level of 3 METs, which was not taken into account in our current analysis. Long-term intervention studies on the effects of physical activity with (very) low intensity on disease outcomes are lacking.

Footnotes

We thank Firstbeat Technologies Ltd for providing the data for analysis. We also thank Kaisa Hämäläinen, Jaakko Kotisaari, and Tero Myllymäki, Firstbeat Technologies Ltd, for their assistance in the first stages of data mining and their valuable comments on the methods section of this paper.

Contributors: All authors participated in planning the study design and statistical analyses, revision of the manuscript, and approved the final version. SM and UMK (guarantor) drafted the manuscript. EH and JP carried out the analysis. All researchers were independent of the funders. The study sponsor and funder played no role in study design; the collection, analysis, and interpretation of data; the writing of the report; and the decision to submit the article for publication.

Funding: This work was partially supported by the SalWe Research Program for Mind and Body (Tekes - the Finnish Funding Agency for Technology and Innovation grant 1104/10).

Ethical approval: This study was approved by the Ethics Committee of Tampere University Hospital (Reference No R13160).

Competing interests: All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure .pdf and declare: all authors had financial support from Tekes (The Finnish Funding Agency for Innovation) for the submitted work; EH, JP and IK report research grant from Firstbeat Technologies Ltd, during the conduct of the study; EH, JP and IK report other research grant from Firstbeat Technologies Ltd, outside the submitted work; and IK is a co-founder in PulseOn Ltd which is a company developing optical heart rate monitoring technology, www.pulseon.com; other authors report no financial relationships with any organizations that might have an interest in the submitted work in the past three

years; other authors report no other relationships or activities that could appear to have influenced the submitted work.

Transparency: The lead author (the manuscript's guarantor) affirms that the manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

Data sharing: No additional data available.

An Exclusive licence: The Corresponding Author has the right to grant on behalf of all authors and does grant on behalf of all authors, a worldwide licence (http://www.bmj.com/sites/default/files/BMJ%20Author%20Licence%20March%202013.doc) to the Publishers and its licensees in perpetuity, in all forms, formats and media (whether known now or created in the future), to i) publish, reproduce, distribute, display and store the Contribution, ii) translate the Contribution into other languages, create adaptations, reprints, include within collections and create summaries, extracts and/or, abstracts of the Contribution and convert or allow conversion into any format including without limitation audio, iii) create any other derivative work(s) based in whole or part on the Contribution, iv) to exploit all subsidiary rights that currently exist or as may exist in the future in the Contribution, v) the inclusion of electronic links from the Contribution to third party material where-ever it may be located; and, vi) licence any third party to do any or all of the above. All research articles will be made available on an Open Access basis (with authors being asked to pay an open access fee—see http://www.bmj.com/about-bmj/resources-authors/forms-policies-and-checklists/copyright-open-access-and-permission-reuse). The terms of such Open Access shall be governed by a Creative Commons licence—details as to which Creative Commons

licence will apply to the research article are set out in our worldwide licence referred to above.

References

1. Pan XR, Li GW, Hu YH, Wang JX, Yang WY, An ZX, et al. Effects of diet and exercise in preventing NIDDM in people with impaired glucose tolerance. The Da Qing IGT and Diabetes Study. *Diabetes Care* 1997;20:537-44.
2. Ohkawara K, Tanaka S, Miyachi M, Ishikawa-Takata K, Tabata I. A dose-response relation between aerobic exercise and visceral fat reduction: Systematic review of clinical trials. *Int J Obes* 2007;31:1786-97.
3. Physical Activity Guidelines Advisory Committee. Physical Activity Guidelines Advisory Committee Report, 2008. Washington, DC: U.S. Department of Health and Human Services; 2008.
4. Waller K, Kaprio J, Lehtovirta M, Silventoinen K, Koskenvuo M, Kujala UM. Leisure-time physical activity and type 2 diabetes during a 28-year follow-up in twins. *Diabetologia* 2010;53:2531-7.
5. Kujala UM, Mäkinen V-P, Heinonen I, Soininen P, Kangas AJ, Leskinen TH, et al. Long-term leisure-time physical activity and serum metabolome. *Circulation* 2013;127:340-8.
6. Sattelmair J, Pertman J, Ding EL, Kohl III HW, Haskell W, Lee I-M. Dose response between physical activity and risk of coronary heart disease. A meta-analysis. *Circulation* 2011;124:789-95.
7. Li J, Siegrist J. Physical activity and risk of cardiovascular disease - A meta-analysis of prospective cohort studies. *Int J Environ Res Public Health* 2012;9:391-407.
8. Reiner M, Niermann C, Jekauc D, Woll A. Long-term health benefits of physical activity - A systematic review of longitudinal studies. *BMC Public Health* 2013;13:813.
9. Mammen G, Faulkner G. Physical activity and the prevention of depression. A systematic review of prospective studies. *Am J Prev Med* 2013;45:649-57.

10. Samitz G, Egger M, Zwahlen M. Domains of physical activity and all-cause mortality: Systematic review and dose-response meta-analysis of cohort studies. *Int J Epidemiol* 2011;40:1382-1400.

11. World Health Organization. Global recommendations on physical activity for health. Geneva: World Health Organization; 2010.

12. Garber CE, Blissmer B, Deschenes MR, Franklin BA, Lamonte MJ, Lee I-M, et al. American College of Sports Medicine Position Stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: Guidance for prescribing exercise. *Med Sci Sports Exerc* 2011, 1334-59. doi:10.1249/MSS.0b013e318213fefb

13. Butte NF, Ekelund U, Westerterp KR. Assessing physical activity using wearable monitors: Measures of physical activity. *Med Sci Sports Exerc* 2012;44:S5-S12.

14. Archer E, Hand GA, Hébert JR, Lau EY, Wang X, Shook RP, et al. Validation of a novel protocol for calculating estimated energy requirements and average daily physical activity ratio for the US population: 2005-2006. *Mayo Clin Proc* 2013;88:1398-1407.

15. Westerterp KR. Assessment of physical activity: A critical appraisal. *Eur J Appl Physiol* 2009;105:823-8.

16. Hagströmer M, Oja P, Sjöström M. Physical activity and inactivity in an adult population assessed by accelerometry. *Med Sci Sports Exerc* 2007;39:1502-8.

17. Tucker JM, Welk GJ, Beyler NK. Physical activity in U.S. adults. Compliance with the Physical Activity Guidelines for Americans. *Am J Prev Med* 2011;40:454-61.

18. Hansen BH, Holme I, Anderssen SA, Kolle E. Patterns of objectively measured physical activity in normal weight, overweight, and obese individuals (20-85 years): A cross-sectional study. *PLos ONE* 2013;8(1):e53044. doi:10.1371/journal.pone.0053044

19. Achten J, Jeukendrup AE. Heart rate monitoring. Applications and limitations. *Sports Med* 2003;33:517-38.

20. Smolander J, Ajoviita M, Juuti T, Nummela A, Rusko H. Estimating oxygen consumption from heart rate and heart rate variability without individual calibration. *Clin Physiol Funct Imaging* 2011;31:266-71.

21. Teisala T, Mutikainen S, Tolvanen A, Rottensteiner M, Leskinen T, Kaprio J, et al. Associations of physical activity, fitness, and body composition with heart rate variability-based indicators of stress and recovery on workdays: A cross-sectional study. *J Occup Med Toxicol* 2014;9:16. doi:10.1186/1745-6673-9-16

22. Firstbeat Technologies Ltd. EPOC based training effect assessment [White paper]. Published Sep 2005, updated March 2012. Available from: http://www.firstbeat.com/userData/firstbeat/download/white_paper_training_effect.pdf

23. Ross RM, Jackson AS. Exercise concepts, calculations, and computer applications. Carmel, Indiana: Benchmark press; 1990.

24. Jones NL. Clinical exercise testing. 3rd ed. Philadelphia: W.B. Saunders; 1988.

25. Jackson AS, Blair SN, Mahar MT, Wier LT, Ross RM, Stuteville JE. Prediction of functional aerobic capacity without exercise testing. *Med Sci Sports Exerc* 1990;22:863-70.

26. Saalasti S. Neural networks for heart rate time series analysis [dissertation]. Jyväskylä, Finland: University of Jyväskylä; 2003. Available from: https://jyx.jyu.fi/dspace/bitstream/handle/123456789/13267/951391707X.pdf?sequence=1

27. Kettunen J, Saalasti S, inventors; Firstbeat Technologies Ltd, assignee. Procedure for deriving reliable information on respiratory activity from heart period measurement. United States patent US 7,460,901 B2. 2008 Dec 2. Available from: http://worldwide.espacenet.com/publicationDetails/originalDocument?CC=US&NR=7460901B2&KC=B2&FT=D&ND=4&date=20081202&DB=EPODOC&locale=fi_FI

28. Kettunen J, Saalasti S, inventors; Firstbeat Technologies Ltd, assignee. Procedure for detection of stress by segmentation and analyzing heart beat signal. United States patent US 7,330,752 B2. 2008 Feb 12. Available from: http://worldwide.espacenet.com/publicationDetails/originalDocument?FT=D&date=20080212&DB=EPODOC&locale=fi_FI&CC=US&NR=7330752B2&KC=B2&ND=4

29. Firstbeat Technologies Ltd. VO_2 estimation method based on heart rate measurement [White paper]. Published Feb 2005, updated March 2012. Available from: http://www.firstbeat.com/userData/firstbeat/download/white_paper_vo2_estimation.pdf

30. Kang M, Bassett DR, Barreira TV, Tudor-Locke C, Ainsworth B, Reis JP, et al. How many days are enough? A study of 365 days of pedometer monitoring. *Res Q Exerc Sport* 2009;80:445-53.

31. Troiano RP, Berrigan D, Dodd KW, Mâsse LC, Tilert T, McDowell M. Physical activity in the United States measured by accelerometer. *Med Sci Sports Exerc* 2008;40:181-8.

32. Husu P, Suni J, Vähä-Ypyä H, Sievänen H, Tokola K, Valkeinen H, et al. The level of physical activity and sedentary behaviour in Finnish adults. *Suomen Lääkärilehti* 2014;69:1860-6. (in Finnish; abstract available in English).

33. Helakorpi S, Laitalainen E, Uutela A. Health behaviour and health among the Finnish adult population, spring 2009. National Institute for Health and Welfare (THL), Report 7/2010. (in Finnish; abstract, tables and figures available in English).

34. Hu FB, Willett WC, Li T, Stampfer MJ, Colditz GA, Manson JE. Adiposity as compared with physical activity in predicting mortality among women. *N Engl J Med* 2004;351:2694-703.

35. Pietiläinen KH, Kaprio J, Borg P, Plasqui G, Yki-Järvinen H, Kujala UM, et al. Physical inactivity and obesity: A vicious circle. *Obesity* 2008;16:409-14.

36. Strath SJ, Kaminsky LA, Ainsworth BE, Ekelund U, Freedson PS, Gary RA, et al. Guide to the assessment of physical activity: Clinical and research applications: A scientific statement from the American Heart Association. *Circulation* 2013;128:2259-79.

Table 1 Distributions of participants into moderate-to-vigorous and vigorous physical activity categories according to mean minutes per day on workdays and days off

	Workdays				Days off			
	0 min n (%)	>0-15 min n (%)	>15-30 min n (%)	>30 min n (%)	0 min n (%)	>0-15 min n (%)	>15-30 min n (%)	>30 min n (%)
Men (n=4221)								
$MVPA_{1min}$	91 (2.2)	835 (19.8)	706 (16.7)	2589 (61.3)	160 (3.8)	851 (20.2)	563 (13.3)	2647 (62.7)
$MVPA_{10min}$	1345 (31.9)	712 (16.9)	802 (19.0)	1362 (32.3)	1535 (36.4)	452 (10.7)	500 (11.8)	1734 (41.1)
VPA_{1min}	1544 (36.6)	1571 (37.2)	658 (15.6)	448 (10.6)	1862 (44.1)	1221 (28.9)	391 (9.3)	747 (17.7)
VPA_{10min}	3014 (71.4)	524 (12.4)	441 (10.4)	242 (5.7)	3189 (75.6)	236 (5.6)	292 (6.9)	504 (11.9)
Women (n=5333)								
$MVPA_{1min}$	480 (9.0)	1632 (30.6)	1015 (19.0)	2206 (41.4)	838 (15.7)	1612 (30.2)	760 (14.3)	2123 (39.8)
$MVPA_{10min}$	2523 (47.3)	913 (17.1)	864 (16.2)	1033 (19.4)	2999 (56.2)	469 (8.8)	550 (10.3)	1315 (24.7)
VPA_{1min}	3200 (60.0)	1454 (27.3)	440 (8.3)	239 (4.5)	3651 (68.5)	979 (18.4)	299 (5.6)	404 (7.6)
VPA_{10min}	4520 (84.8)	408 (7.7)	294 (5.5)	111 (2.1)	4690 (87.9)	196 (3.7)	169 (3.2)	278 (5.2)

$MVPA_{1min}$=moderate-to-vigorous physical activity (≥3 metabolic equivalents [METs]) calculated from single 1-minute bouts throughout the measurement period

$MVPA_{10min}$= moderate-to-vigorous physical activity (≥3 METs) calculated from bouts of physical activity lasting continuously for ≥10 minutes

VPA_{1min}=vigorous physical activity (≥6 METs) calculated from single 1-minute bouts throughout the measurement period

VPA_{10min}=vigorous physical activity (≥6 METs) calculated from bouts of physical activity lasting continuously for ≥10 minutes

Table 2 Amount of moderate-to-vigorous and vigorous physical activity during workdays and days off based on age group

	n (men/women)		Men Workdays (min/day)	Men Days off (min/day)	Men P*	Women Workdays (min/day)	Women Days off (min/day)	Women P*
$MVPA_{1min}$								
18-30 yrs	366/457	mean (SD)	88.6 (72.8)†	88.3 (75.7)†	0.81	76.6 (53.5)†	71.5 (61.9)†	0.005
		median	67.5†	69.0†		69.0†	60.0†	
31-40 yrs	1109/1251	mean (SD)	55.7 (44.2)†	67.7 (63.2)†	<0.001	42.1 (38.5)†	40.8 (40.6)†	0.041
		median	47.0†	52.3†		34.0†	28.0†	
41-50 yrs	1411/1905	mean (SD)	47.1 (42.5)†	59.9 (56.5)†	<0.001	28.3 (29.1)†	31.1 (37.1)†	0.34
		median	36.5†	47.0†		21.0†	17.0†	
51-65 yrs	1335/1720	mean (SD)	42.9 (46.2)†	53.3 (56.0)†	<0.001	20.5 (24.4)†	22.7 (33.3)†	0.74
		median	31.0†	37.5†		11.0†	8.0†	
VPA_{1min}								
18-30 yrs	366/457	mean (SD)	17.0 (21.4)†	17.6 (25.3)†	0.73	16.5 (19.9)†	15.1 (23.1)†	0.004
		median	10.0†	5.0†		9.0†	4.0†	
31-40 yrs	1109/1251	mean (SD)	11.6 (16.6)†	15.9 (24.4)†	<0.001	7.8 (12.7)†	8.1 (15.9)†	0.16
		median	4.0†	3.0†		1.0†	0.0†	
41-50 yrs	1411/1905	mean (SD)	9.9 (14.7)†	13.9 (24.9)†	<0.001	4.0 (9.1)†	5.8 (14.9)†	0.008
		median	2.0†	1.0†		0.0†	0.0†	
51-65 yrs	1335/1720	mean (SD)	7.4 (13.9)†	10.2 (21.2)†	0.003	1.8 (6.3)†	2.5 (11.2)†	0.54
		median	0.5†	0.0†		0.0†	0.0†	

* For the difference between workdays and days off by Wilcoxon two-sample paired signed rank test

† P<0.001 for the difference between age groups by Kruskal-Wallis test

$MVPA_{1min}$=moderate-to-vigorous physical activity (≥3 metabolic equivalents [METs]) calculated from single 1-minute bouts throughout the measurement period

VPA_{1min}=vigorous physical activity (≥6 METs) calculated from single 1-minute bouts throughout the measurement period

Table 3 Amount of moderate-to-vigorous and vigorous physical activity during workdays and days off based on weight status

	n (men/women)		Men Workdays (min/day)	Men Days off (min/day)	Men P*	Women Workdays (min/day)	Women Days off (min/day)	Women P*
$MVPA_{1min}$								
Normal weight	1495/2792	mean (SD)	60.1 (53.5)†	74.0 (67.4)†	<0.001	44.5 (39.6)†	46.4 (46.7)†	0.99
		median	48.0†	58.5†		35.5†	35.0†	
Overweight	2067/1627	mean (SD)	49.4 (46.2)†	60.0 (56.4)†	<0.001	24.5 (30.1)†	25.2 (33.0)†	0.60
		median	38.0†	46.0†		16.0†	12.0†	
Obese	659/914	mean (SD)	39.6 (43.5)†	42.9 (52.0)†	0.18	13.9 (21.3)†	12.6 (21.8)†	0.001
		median	29.0†	26.0†		4.8†	2.0†	
VPA_{1min}								
Normal weight	1495/2792	mean (SD)	13.2 (17.3)†	18.2 (27.4)†	<0.001	8.4 (13.8)†	10.0 (19.2)†	0.65
		median	5.5†	4.0†		1.0†	0.0†	
Overweight	2067/1627	mean (SD)	9.6 (15.5)†	12.6 (22.3)†	<0.001	2.5 (7.9)†	2.6 (9.1)†	0.44
		median	1.5†	1.0†		0.0†	0.0†	
Obese	659/914	mean (SD)	5.0 (11.3)†	6.1 (16.3)†	0.97	0.6 (3.1)†	0.5 (3.5)†	0.07
		median	0.0†	0.0†		0.0†	0.0†	

Normal weight=18.5 to <25.0 kg/m^2; overweight=25.0 to <30.0 kg/m^2; obese=30.0 to 40.0 kg/m^2

* For the difference between workdays and days off by Wilcoxon two-sample paired signed rank test

† P<0.001 for the difference between body mass index groups by Kruskal-Wallis test

$MVPA_{1min}$=moderate-to-vigorous physical activity (≥3 metabolic equivalents [METs]) calculated from single 1-minute bouts throughout the measurement period

VPA_{1min}=vigorous physical activity (≥6 METs) calculated from single 1-minute bouts throughout the measurement period

Table 4 Predictors of the amount of moderate-to-vigorous and vigorous physical activity

	$MVPA_{1min}$		VPA_{1min}	
	Unstandardized regression coefficient (95% CI)	**P**	**Unstandardized regression coefficient (95% CI)**	**P**
Age (18 yrs=0)	-1.130 (-1.203 to -1.056)	<0.001	-0.286 (-0.310 to -0.261)	<0.001
Gender (1=men; 0=women)	24.352 (22.930 to 25.773)	<0.001	6.584 (6.114 to 7.054)	<0.001
Body mass index (18.5 kg/m^2=0)	-2.464 (-2.639 to -2.288)	<0.001	-0.762 (-0.820 to -0.704)	<0.001
Type of day (1=workday; 0=day off)	-5.161 (-6.051 to -4.271)	<0.001	-1.934 (-2.312 to -1.556)	<0.001

$MVPA_{1min}$=moderate-to-vigorous physical activity (≥3 metabolic equivalents [METs]) calculated from single 1-minute bouts throughout the measurement period

VPA_{1min}=vigorous physical activity (≥6 METs) calculated from single 1-minute bouts throughout the measurement period

The dependent variables in the linear mixed effects regression models were $MVPA_{1min}$ and VPA_{1min} (minutes/day) as continuous variables.

Table 5 Probability of having a bout of moderate-to-vigorous or vigorous physical activity (per measurement day) lasting continuously for ≥10 minutes

	MVPA		VPA	
	Unstandardized regression coefficient (95% CI)	P	Unstandardized regression coefficient (95% CI)	P
Simple models				
Age (18 yrs=0)	-0.040 (-0.043 to -0.036)	<0.001	-0.047 (-0.052 to -0.042)	<0.001
Gender (1=men; 0=women)	0.948 (0.881 to 1.016)	<0.001	1.263 (1.163 to 1.363)	<0.001
Body mass index (18.5 kg/m^2=0)	-0.139 (-0.148 to -0.130)	<0.001	-0.186 (-0.202 to -0.171)	<0.001
Type of day (1=workday; 0=day off)	-0.189 (-0.242 to -0.135)	<0.001	-0.244 (-0.322 to -0.167)	<0.001
Interaction models				
Age (18 yrs=0)	-0.023 (-0.031 to -0.014)	<0.001	-0.032 (-0.043 to -0.021)	<0.001
Gender (1=men; 0=women)	-0.157 (-0.400 to 0.086)	0.21	-0.764 (-1.100 to -0.427)	<0.001
Body mass index (18.5 kg/m^2=0)	-0.078 (-0.107 to -0.050)	<0.001	-0.126 (-0.170 to -0.081)	<0.001
Type of day (1=workday; 0=day off)	0.135 (-0.049 to 0.319)	0.15	0.004 (-0.231 to 0.240)	0.97
Age*Body mass index	-0.003 (-0.004 to -0.002)	<0.001	-0.006 (-0.008 to -0.004)	<0.001
Gender*Age	0.030 (0.022 to 0.037)	<0.001	0.058 (0.047 to 0.068)	<0.001
Gender*Body mass index	0.068 (0.050 to 0.086)	<0.001	0.116 (0.085 to 0.147)	<0.001
Type of day*Age	-0.009 (-0.015 to -0.004)	0.001	-0.016 (-0.024 to -0.008)	<0.001
Type of day*Gender	-0.349 (-0.460 to -0.238)	<0.001	-0.188 (-0.364 to -0.013)	0.035
Type of day*Body mass index	0.012 (-0.003 to 0.027)	0.12	0.040 (0.013 to 0.066)	0.003

MVPA=moderate-to-vigorous physical activity (≥3 metabolic equivalents [METs]); VPA=vigorous physical activity (≥6 METs)

The results are from the generalized linear mixed effects regression models in which the dependent variables are binary outcomes (participant did or did not have a bout of moderate-to-vigorous or vigorous physical activity lasting ≥10 minutes) and each participant is incorporated as a random effect. In the simple models, the fixed effects are age, gender, body mass index, and type of day. In the interaction models, the fixed effects are age, gender, body mass index, type of day, and all of their possible two-way interactions.

Table 6 Proportion of participants fulfilling the aerobic physical activity recommendation* based on gender and weight status

	Men	Women
	% (95% CI)	**% (95% CI)**
$MVPA_{1min}$		
All	80.0 (78.8 to 81.2)	56.1 (54.7 to 57.4)
Normal weight	88.6 (86.8 to 90.1)	74.1 (72.4 to 75.7)
Overweight	79.4 (77.6 to 81.1)	43.8 (41.3 to 46.2)
Obese	62.5 (58.7 to 66.2)	23.0 (20.3 to 25.8)
$MVPA_{10min}$		
All	54.3 (52.8 to 55.8)	32.8 (31.6 to 34.1)
Normal weight	64.9 (62.4 to 67.3)	46.5 (44.6 to 48.3)
Overweight	52.7 (50.5 to 54.9)	22.1 (20.1 to 24.2)
Obese	35.5 (31.9 to 39.3)	10.3 (8.4 to 12.4)

* Moderate intensity aerobic physical activity at least 150 minutes per week, vigorous physical activity at least 75 minutes per week, or a combination of these (for details of calculation, see methods)

Normal weight=18.5 to <25.0 kg/m^2; overweight=25.0 to <30.0 kg/m^2; obese=30.0 to 40.0 kg/m^2

$MVPA_{1min}$= moderate-to-vigorous physical activity (≥3 metabolic equivalents [METs]) calculated from single 1-minute bouts throughout the measurement period

$MVPA_{10min}$= moderate-to-vigorous physical activity (≥3 METs) calculated from bouts of physical activity lasting continuously for ≥10 minutes

Figure legends

Figure 1 Flow of participants and measurement days included in the analysis.

Figure 2 The mean amount of moderate-to-vigorous physical activity (≥3 metabolic equivalents [METs]) (whole column) and its distribution into moderate (MPA; 3 to <6 METs) and vigorous (VPA; ≥6 METs) physical activity during workdays (WD) and days off (DO) by age among men and women. The 1 min notation indicates values for single 1-minute bouts throughout the measurement period, whereas the 10 min notation indicates values for bouts of physical activity lasting continuously for ≥10 minutes. P_3 and P_6 denote the differences between WD and DO in moderate-to-vigorous and vigorous physical activities, respectively. *physical activity was greater during WD than DO. Note the different scales between the upper and lower figures.

Figure 3 The mean amount of moderate-to-vigorous physical activity (≥3 metabolic equivalents [METs]) (whole column) and its distribution into moderate (MPA; 3 to <6 METs) and vigorous (VPA; ≥6 METs) physical activity during workdays (WD) and days off (DO) by weight status among men and women. Normal weight=18.5 to <25.0 kg/m^2; overweight=25.0 to <30.0 kg/m^2; obese=30.0 to 40.0 kg/m^2. The 1 min notation indicates values for single 1-minute bouts throughout the measurement period, whereas the 10 min notation indicates values for bouts of physical activity lasting continuously for ≥10 minutes. P_3 and P_6 denote the differences between WD and DO in moderate-to-vigorous and vigorous physical activities, respectively. *physical activity was greater during WD than DO. Note the different scales between the upper and lower figures.

Figure 4 Hourly distributions of moderate-to-vigorous (MVPA; ≥3 metabolic equivalents [METs]) and vigorous (VPA; ≥6 METs) physical activity by gender and weight status during workdays and days off. The mean number of minutes at a certain hour (e.g., 9 am) denotes

the number of minutes during the hour beginning from that time point (e.g., 9-10 am). Normal weight=18.5 to <25.0 kg/m^2; overweight=25.0 to <30.0 kg/m^2; obese=30.0 to 40.0 kg/m^2. The 1 min notation indicates values for single 1-minute bouts throughout the measurement period.

Figure 5 The proportion of participants fulfilling the aerobic physical activity recommendation (moderate intensity physical activity for at least 150 minutes per week, vigorous physical activity at least 75 minutes per week, or a combination of these) based on gender and weight status. Normal weight=18.5 to <25.0 kg/m^2; overweight=25.0 to <30.0 kg/m^2; obese=30.0 to 40.0 kg/m^2. Note the different scales between the upper and lower figures.

Objectively measured physical activity in Finnish employees: a cross-sectional study

Sara Mutikainen, Elina Helander, Julia Pietilä, Ilkka Korhonen, Urho M. Kujala

Department of Health Sciences, University of Jyväskylä, Jyväskylä, Finland Sara Mutikainen post-doctoral researcher, Urho M Kujala professor

Department of Signal Processing, Tampere University of Technology, Tampere, Finland Elina Helander post-doctoral researcher, Julia Pietilä research assistant, Ilkka Korhonen professor

VTT Technical Research Center of Finland, Tampere, Finland Ilkka Korhonen professor

Correspondence to:

Urho M. Kujala, M.D., Ph.D., Department of Health Sciences, University of Jyväskylä, P.O.Box 35 (LL), FI-40014 University of Jyväskylä, Finland

Tel: +358408053567, Fax: +35814617423, E-mail: urho.m.kujala@jyu.fi

Abstract

Objectives To objectively measure the amount of intensity-specific physical activity by gender and age with respect to body mass index (BMI) during workdays and days off among Finnish employees.

Design A cross-sectional study.

Setting Primary care occupational health care units.

Participants A sample of 9554 Finnish employees (4221 men and 5333 women; age range 18-65 years; BMI range 18.5-40.0 kg/m^2) who participated in health assessments related to occupational health promotion.

Main outcome measurements The amount of moderate-to-vigorous (MVPA) and vigorous (VPA) physical activity (≥3 and ≥6 metabolic equivalents, respectively) was assessed by estimating minute-to-minute oxygen consumption from the recorded beat-to-beat R-R interval data. The estimation method used heart rate, respiration rate, and on/off response information from R-R interval data calibrated by age, gender, height, weight, and self-reported physical activity class. The proportion of participants fulfilling the aerobic physical activity recommendation of ≥150 minutes/week was calculated on the basis of ≥10-minute bouts, multiplying VPA minutes by 2.

Results Both MVPA and VPA were higher among men and during days off, and decreased with increasing age and BMI (P<0.001 for all). Similar results were observed when the probability of having a bout of MVPA or VPA lasting continuously for ≥10 minutes per measurement day was studied. The total amount of VPA was low among overweight (mean ≤2.6 minutes/day), obese (mean ≤0.6 minutes/day), and all 51 to 65-year-old (mean ≤2.5 minutes/day) women during both types of days. The proportion of participants fulfilling the

aerobic physical activity recommendation was highest for normal weight men (65%; 95% CI 62 to 67%) and lowest for obese women (10%; 95% CI 8 to 12%).

Conclusions Objectively measured physical activity is higher among men and during days off and decreases with increasing age and BMI. The amount of VPA is very low among obese, overweight, and older women.

Strengths and limitations of this study

- Using novel validated methodology, our study provides accurate data on intensity-specific physical activity in a large sample of working age individuals, with detailed associations between intensity-specific physical activity and gender, age, body mass index, and the type of day (workday vs. day off) and their interactions.
- The study sample was not a random sample from the population, but a 'real life' clinical sample of employees who participated in preventive occupational health care.
- Our recordings usually covered some typical workdays and days off, a longer recording may be more valid than the duration used in our study.

Introduction

Epidemiological evidence, studies on underlying mechanisms, and intervention studies suggest that physical activity plays an important role in the prevention of body fat accumulation and type 2 diabetes.[1-5] Observational studies suggest that physical activity may also have other health benefits such as reduced risk for cardiovascular disease,[6-8] dementia,[8] depression [9] and mortality.[10] To achieve these health benefits, according to recent recommendations, moderate intensity aerobic physical activity should be performed for at least 150 minutes or vigorous physical activity at least 75 minutes per week.[3 11 12] However, accurately recording the amount and intensity of physical activity with regard to both physical activity-related energy requirements and cardio-respiratory loading is challenging.[13 14] Objective information is usually obtained by heart rate (HR) monitors or motion sensors, such as accelerometers.[15] Existing data suggest that, among obese individuals, the amount of vigorous physical activity is low compared to current recommendations.[14 16-18] However, estimating the cardio-respiratory loading of physical activity among obese and/or unfit individuals is difficult using accelerometers or other motion sensors.

HR monitoring is a common method of assessing the intensity of physical activity in clinical settings. HR is almost linearly associated with oxygen consumption (VO_2) at moderate to submaximal intensities in steady-state exercise; therefore, it can be used to estimate the intensity of steady-state physical activity. However, the intensity of real life physical activity usually changes repeatedly, and the relationship between HR and VO_2 is curvilinear for very low intensity physical activities and near maximal exercise; thus, the actual VO_2 can be over- or underestimated when using the linear HR-VO_2 relationship to estimate the actual VO_2.[19] Continuous measurement of HR variability and experimental calibration of data by age, gender, weight, height, and self-reported physical activity class was recently shown to provide accurate estimates of the intensity of physical activity.[20] We used such novel methodology in this study to estimate the intensity of physical activity in a large sample of Finnish employees.

The aim of this study was to investigate the amount of physical activity among 9554 Finnish employees who had participated in continuous beat-to-beat R-R interval (ECG) recordings during the course of their normal everyday life. More specifically, we investigated the intensity-specific amount of physical activity by gender and age with respect to body mass index (BMI) during workdays vs. days off, including hourly distributions of physical activity throughout the day. This information is an important basis for understanding the cardio-respiratory loading caused by physical activity and the needs and realistic possibilities for interventions that increase physical activity.

Methods

Study design and participants

This study is a cross-sectional study investigating the intensity and amount of physical activity among a clinical sample of 9554 Finnish employees (4221 men and 5333 women; age range 18-65 years; BMI range 18.5-40.0 kg/m^2) who participated in preventive occupational health care provided by their employers during the years 2007-2013 (Figure 1). The participants non-selectively represent a wide range of non-manual and manual labor employees and, thus, a cross-section of typical Finnish employees. As a part of these health care programs, participants performed continuous beat-to-beat R-R interval recordings in the course of their normal everyday life as described below. The clinical purpose of these recordings was to assess the intensity and amount of physical activity (reported in this paper) and other R-R interval -derived information such as the amount of stress and recovery [21] (not reported in this paper) during workdays and days off. To acquire these so-called Lifestyle

Assessment results, the R-R interval data were analyzed using Firstbeat Analysis Server software (Firstbeat Technologies Ltd, Jyväskylä, Finland). On the basis of the results, the participants received personal feedback and recommendations for maintaining or improving their health and wellbeing.

The majority of the participants in this study were apparently healthy. The exclusion criteria for participation in the R-R interval recordings represented by the analysis software manufacturer were: chronic rhythm disturbance, cardiac pacemaker or transplant, left bundle branch block, severe cardiac disease (e.g., symptomatic coronary heart disease, heart failure), very high blood pressure (≥180/100 mmHg), type 1 or 2 diabetes with autonomic neuropathy, hyperthyreosis or other disturbances of the thyroid gland leading to a resting HR >80 bpm, severe neurological disease (e.g., advanced multiple sclerosis or Parkinson's disease), fever or other acute disease, and BMI >40.0 kg/m^2. Cases of milder/early disease stages and some medications may affect R-R intervals or physical activity levels. The inclusion/exclusion of these participants from the R-R interval recordings was evaluated on a case-by-case basis in the occupational health care programs.

The data obtained from these R-R interval recordings were analyzed and anonymously stored in a database administered by the software manufacturer (Firstbeat Technologies Ltd). Firstbeat Technologies Ltd and each service provider (e.g., occupational health care unit) who conducted the recordings for employees (participants) signed an agreement providing Firstbeat Technologies Ltd the right to store the data in an anonymized form and to use it for development and research purposes with a statement that employers must inform their employees about its use. According to the agreement, Firstbeat Technologies Ltd extracted an anonymous data file from the registry for the present research purposes.

Physical activity assessment

The ambulatory beat-to-beat R-R interval data used to calculate the intensity and amount of physical activity were recorded during the course of normal everyday life, usually over three days (typically including two workdays and one day off), using the Firstbeat Bodyguard device (Firstbeat Technologies Ltd). Data from the measurements were analyzed using Firstbeat Analysis Server software (version 5.6.0.3, Firstbeat Technologies Ltd). To be included in the analyses (Figure 1), a participant had to have a measurement period including at least one workday and one day off. We included a workday or a day off in the analysis if the measurement period lasted >16 hours/day. The information about workdays and days off was obtained from the diaries the participants were asked to fill in during the measurement period. A day was considered to be a workday if a participant worked ≥4 hours cumulatively. The days without any working hours were regarded as days off and the days with work time < 4 hours were excluded from the analyses. The analyzed data consisted of successfully recorded (measurement error <15% and <30 minute recording break) workdays and days off (Figure 1). The Firstbeat Bodyguard device cannot be used during swimming. Since we accepted only measurement days with <30 minute recording breaks, the days with longer watersports sessions (≥30 minutes) are excluded from our analyses.

Background information included age, gender, self-reported height and weight, and self-reported physical activity class[22] modified from Ross and Jackson.[23] This information was collected in conjunction with R-R interval recordings using questionnaires. Background information was used to estimate maximal HR[24] and maximal VO_2,[25] which were used in the estimation of VO_2. If a period with HR higher than the estimated was found from the recording, the maximal HR used for further calculations was corrected accordingly. For the statistical analyses, BMI was calculated from the self-reported weight and height as kilograms per meters squared.

The intensity and amount of physical activity was estimated based on the R-R interval recordings.[26-29] The method was validated previously; the pooled relationship (correlation) between the measured and predicted VO_2 across the different activities of daily living was 0.93 and the estimated VO_2 explained 87% of the variability in the measured VO_2.[20] The high validity of this method was achieved by taking into account the R-R interval-derived information about HR, respiration rate, and on/off response (increasing or decreasing HR) using neural network modeling of the data and short time Fourier Transform method.[26-29]

The participant's mean VO_2 for each minute during each measurement day was calculated from the second-by-second VO_2 estimations. The minute-by-minute VO_2 estimations were then converted to multiples of the resting metabolic rate (METs) by dividing the VO_2 values by 3.5. Based on the MET values, the amount of physical activity (minutes/day) at a certain intensity level was calculated two ways. First, we searched the recordings for single 1-minute segments in which the intensity reached the following MET thresholds: moderate physical activity (MPA) 3 to <6 METs, vigorous physical activity (VPA) ≥6 METs, and moderate-to-vigorous physical activity (MVPA) ≥3 METs,[12] which are referred to as MPA_{1min}, VPA_{1min}, and $MVPA_{1min}$ later in the text. The total number of 1-minute segments above the given thresholds during each measurement day was then calculated. These calculations were performed separately for workdays and days off. If a participant's measurement period included two or more workdays (or days off), an average was calculated. Second, because the recommendation for health-enhancing physical activity suggests that the duration of a bout of aerobic activity should be 10 continuous minutes or longer,[3 11 12] we utilized this in our calculations for different intensity categories, which are referred to as MPA_{10min}, VPA_{10min}, and $MVPA_{10min}$ later in the text. In this case, we calculated the total number of 1-minute segments above the given intensity thresholds during each measurement day using only the bouts of physical activity that lasted continuously for ≥10 minutes. The consecutive 1-minute segments had to be above the given intensity thresholds for at least 10 minutes, except for one 1-minute segment, which was allowed to be less than the given threshold. Otherwise the calculations were performed using the same principles as described above for single 1-minute segments.

Analysis

Data processing and statistical analysis were performed using MATLAB version R2013b (The MathWorks Inc., Natick, Massachusetts, U.S.A.) and R version 3.0.2 (The R Foundation for Statistical Computing, Vienna, Austria). All P values were two-sided and $P<0.05$ was considered statistically significant.

We calculated means, standard deviations, and medians for continuous variables and frequencies and proportions for categorical variables. We categorized the amount of MVPA and VPA into four categories (0, >0 to 15, >15 to 30 and >30 min) and calculated the distribution of participants in these categories by gender and type of day (i.e., workdays vs. days off). We also calculated the amount of MVPA and VPA by gender and type of day for different age categories (18-30, 31-40, 41-50, and 51-65 years) and BMI categories (normal weight 18.5 to <25.0 kg/m^2, overweight 25.0 to <30.0 kg/m^2, and obese 30.0 to 40.0 kg/m^2). The amount of MVPA and VPA during the workdays and days off were compared by gender inside each age and BMI category using the Wilcoxon two-sample paired signed rank test. The test assessed whether the differences in the amount of MVPA and VPA between each participant's workdays and days off came from a distribution with a median of zero. Differences in the amount of MVPA and VPA between age categories and between BMI categories were analyzed using the Kruskal-Wallis test. To describe the temporal distribution of physical activity, we calculated the amount of MVPA and VPA in each hour (e.g., from 9 am to 10 am, from 10 am to 11 am, etc.) during the day by gender, BMI category, and type of day. For illustrative reasons, the means are shown in all figures instead of medians.

The probability of having at least one 10-minute bout of MVPA or VPA per measurement day (binary outcome; yes vs. no) was modeled using a generalized linear mixed effects regression (procedure *glmer* with Laplace approximation in R). Each participant was incorporated as a random effect, and fixed effects included age and BMI as continuous variables and gender and type of day as binary variables. In the modeling, we also included all of the possible two-way interactions among these four variables. We also used linear mixed effects regression (procedure *fitlme* with maximum likelihood estimation in MATLAB) to predict the amount of $MVPA_{1min}$ and VPA_{1min}. In this case, each participant was incorporated as a random effect and fixed effects included age, BMI, gender, and type of day. The baselines for age (minimum 18) and BMI (minimum 18.5) were subtracted from age and BMI data, respectively, before regression calculations.

We also investigated how participants fulfill the aerobic physical activity recommendations of moderate intensity physical activity at least 150 minutes per week or vigorous physical activity at least 75 minutes per week as measured from ≥10-minute bouts of activity.[3] First, we calculated the activity minutes score for each day (MPA minutes + VPA minutes x 2) and then extrapolated the amount of physical activity using the following formula: Weekly physical activity = (5 x mean workday activity score) + (2 x mean day off activity score). This calculation was performed with only the bouts of physical activity lasting continuously for ≥10 minutes as recommended,[3] and then with all ≥1-minute bouts.

Results

Most of the R-R-interval recordings were from three days (7685 participants); there were 1394, 319, 119, and 37 participants who had two, four, five, and six measurement days, respectively. Altogether, the number of analyzed days was 17020 for workdays and 10916 for days off. The mean (SD) age of the participants was 44.8 (9.7) years [men 44.7 (9.7); women 44.9 (9.7)] and the mean (SD) BMI was 26.1 (4.1) kg/m^2 [men 26.7 (3.5); women 25.7 (4.4)].

Table 1 shows the distributions of participants into the MVPA and VPA categories by workdays and days off among the 4221 men and 5333 women who participated in this study. For more than 60% of men and approximately 40% of women, the amount of $MVPA_{1min}$ was more than 30 minutes per day, regardless of the type of day, whereas 11% (workdays) and 18% (days off) of men and 4% (workdays) and 8% (days off) of women had VPA_{1min} for more than 30 minutes per day. All these percentages were clearly lower for $MVPA_{10min}$ and VPA_{10min}.

Figure 2 and Table 2 show the amount of MVPA and VPA by age, gender, and the type of day. The amount of MVPA and VPA decreased with advancing age, especially among women. Among men aged 31 years and older, the amounts of $MVPA_{1min}$, $MVPA_{10min}$, VPA_{1min}, and VPA_{10min} were greater during days off than during workdays. Among younger women (18-40 years), the amount of $MVPA_{1min}$ was lower during days off compared to working days, whereas the amount of $MVPA_{10min}$ was higher during days off among older women (41-65 years). Other clear trends were not observed among women.

Figure 3 and Table 3 show the amount of MVPA and VPA by weight status, gender, and the type of day. Obese participants had less MVPA and VPA than normal weight and overweight participants, especially women. The mean amount of VPA_{1min} was approximately 0.5 minutes per day among obese women, for both workdays and days off. Among obese men, the mean amount of VPA_{1min} was 5.0 minutes during workdays and 6.1 minutes during days off. The mean amount of VPA_{1min} was also low among overweight women (~2.5 minutes per day for both workdays and days off). Among normal weight and overweight men, the amount of

$MVPA_{1min}$, $MVPA_{10min}$, VPA_{1min}, and VPA_{10min} were all greater during days off than workdays, but these differences were not observed among obese men. The corresponding results for women were more complex. Normal weight and overweight women had more $MVPA_{10min}$ during days off than during workdays. However, the amount of $MVPA_{1min}$ was similar between the types of days. On the other hand, obese women had a lower amount of $MVPA_{1min}$ during days off than workdays, but the amount of $MVPA_{10min}$ was similar between the types of day. Differences between workdays and days off with regard to VPA were observed for normal weight women; VPA_{10min} was higher during days off than workdays.

Hourly distributions of MVPA and VPA by gender, weight status, and type of day are shown in Figure 4. The largest amounts of MVPA during workdays occurred at 7-8 am and 5-7 pm. During days off, the largest amounts of MVPA were distributed evenly between 10 am and 6 pm. The respective VPA profiles resemble those of MVPA. During workdays, a small peak occurred at 7-8 am, but the greatest amount of VPA was clearly seen at 5-8 pm. The greatest amount of VPA during days off occurred between 10 am and 8 pm. For both genders, the amount of MVPA and VPA during workdays and days off decreased with increasing BMI.

When age, gender, BMI, and the type of day were included in the linear mixed effects regression models as predictors of the amount of $MVPA_{1min}$ or VPA_{1min} (Table 4), the predictors associated with both outcome measures in similar manners. The amount of $MVPA_{1min}$ and VPA_{1min} decreased with increasing age and increasing BMI. The amounts of $MVPA_{1min}$ and VPA_{1min} were higher among men compared to women and higher during days off than during workdays ($P<0.001$ for all). Similar results were observed when we studied the probability of having a bout of MVPA or VPA (per measurement day) that lasted continuously for ≥10 minutes (Table 5). The probability was higher among men and during days off, and it decreased with increasing age and increasing BMI ($P<0.001$ for all).

We also performed multivariate analysis for the probability of having a bout of MVPA or VPA lasting continuously for ≥10 minutes including two-way interactions between age, gender, BMI, and the type of day (Table 5). Many statistically significant interactions were observed between these variables. Both higher BMI and higher age decreased the likelihood of participating in MVPA or VPA, but BMI affected older participants more than younger participants. In addition, women were more affected by higher age or higher BMI than men. With increasing age, the probability of MVPA or VPA increased for days off compared to workdays. With increasing BMI, the probability of MVPA and VPA increased for workdays compared to days off.

The percentages of participants (by gender and weight status) who fulfilled the aerobic physical activity recommendations are provided in Figure 5 and Table 6. The proportion of participants fulfilling the recommendations decreased with increasing BMI for both men and women. The same was true when the weekly physical activity was calculated including all ≥1-minute bouts. Men fulfilled the recommendations better than women. The proportion fulfilling the recommendations was highest among normal weight men (64.9%, 95% CI 62.4 to 67.3 when ≥10-minute bouts were included in the calculation and 88.6%, 95% CI 86.8 to 90.1 when ≥1-minute bouts were included) and lowest among obese women (10.3%, 95% CI 8.4 to 12.4 and 23.0%, 95% CI 20.3 to 25.8, respectively).

Discussion

We found that the amount of physical activity decreases with increasing age and increasing BMI for both genders, but with a deeper decline among women. The amount of VPA was particularly low among older (51-65 years) and obese and overweight women. Men had more physical activity than women, and physical activity was more common during days off than during workdays, especially among men. The hourly distribution of physical activity clearly differed between workdays and days off. During workdays, physical activity was most common early in the morning and right after working hours, whereas physical activity was distributed more evenly throughout the day during days off. In addition, the proportion of participants fulfilling the aerobic physical activity recommendations decreased with increasing BMI and was lower for women than for men. Approximately one-third of the obese men and one-tenth of obese women fulfilled the aerobic physical activity recommendations.

Strengths and weaknesses of the study

Our study has several strengths. First, our study sample was very large and included a wide range of non-manual and manual labor employees although we did not have individual self-reported information on job titles available for the analysis in our data mining/register –type study. Second, we used a novel ambulatory beat-to-beat R-R interval-based method to assess the intensity of physical activity. This method has been shown to provide more accurate estimates of the intensity of physical activity than HR information only.[20 29] Third, we had strict criteria for the inclusion of recording days (e.g., measurement error <15% and recording break <30 minutes); thus, our recordings had good coverage of typical workdays and days off. Nonetheless, our study also has some weaknesses. Most of the participants were apparently healthy, but some participants with chronic diseases and/or medications that do not severely affect HR were also included in the sample of employees. We did not adjust for these conditions in the analysis since this information was not available for the analysis in our data mining/register –type study. In addition, the study sample was not a random sample from the population, but a 'real life' clinical sample of employees who participated in preventive occupational health care. This can be considered as either a strength or a weakness depending on the perspective. Our method for assessing physical activity can differentiate between the intensities of physical activity MET by MET, but to simplify our presentations, we used cut-off points of ≥3 and ≥6 METs to describe MVPA and VPA, respectively, as these are used in the physical activity recommendations.[12] The durations of our recordings were from two to six days and on the basis of these recordings, the amount of weekly physical activity was estimated in order to determine the proportion of participants who fulfill the aerobic physical activity recommendations. To accurately assess individual long-term physical activity levels, a longer recording is more valid than the duration used in our study.[30] Our recordings usually covered some typical workdays and days off, as our aim was to obtain recordings covering most of the day without artifacts. To achieve this goal, stick-on electrodes with wires were used for the collection of R-R interval data, but in some individuals, the electrodes cause skin irritation that make it difficult to make long recordings.

Findings in relation to other studies

The majority of previous studies including large study populations used accelerometers or pedometers for the objective assessment of physical activity. These methods provide rough estimates of the intensity of physical activity. We used beat-to-beat R-R interval data, which allows more accurate estimations of the intensity of physical activity, but it also has limitations when comparing our results to previous results. The age- and BMI-associated declines in the amount of physical activity observed in our study are in agreement with the results of the studies using accelerometers.[14 17 18 31] In our study, the amount of VPA was very low, especially among older women and overweight and obese women, and similar results have been reported in previous studies that used accelerometers.[14 17 31] Our results on the clear difference between workdays and days off in the hourly distribution of physical activity are in accordance with previous studies.[18] In addition, we observed that the proportions of overweight and obese participants fulfilling the aerobic physical activity recommendations are lower than the proportion of normal weight participants. Previous studies obtained similar results showing that among obese individuals especially the amount of VPA is low compared with the current recommendation.[14 16 18] Previous questionnaire-based studies in Finland have reported that approximately one-quarter [32] to one-half [33] of the working-aged adults (both men and women) fulfill the current aerobic physical activity recommendation. Our objectively measured results (men 54%, women 33%) covering both work-related and leisure physical activities are roughly in line with these results.

Overall, most of the associations in our study are similar to previous population-based studies that used accelerometers. However, our method measures cardio-respiratory loading more directly than the methods based on motion sensors. The amount of physical activity calculated from the bouts lasting ≥10 minutes should be used when determining who meets the current physical activity recommendations.[3] We calculated the amount of MVPA and VPA in two different ways that reflect different aspects of physical activity. The amount of physical activity calculated from single 1-minute bouts throughout the measurement period may be considered to reflect daily activities rather than fitness-enhancing exercise, as this method also takes into account very short bouts of physical activity, such as climbing stairs. Interestingly, the proportion of participants fulfilling the aerobic physical activity recommendation is doubled when shorter bouts are included in the calculation (Table 5).

Meaning of the study: implications for clinicians and policymakers

Increasing physical activity and reducing obesity are both important targets for improving overall population health, as both obesity and low physical activity are predictors of mortality.[34] According to our study approximately one-third of Finnish working-aged women and half of working-aged men meet the current recommendations for aerobic physical activity. The proportion is especially low among overweight and obese women and obese men. On the basis of this and our other observations, the amount of physical activity, especially the amount of VPA, seems to be very low among overweight and obese individuals, particularly women. As our study is cross-sectional in nature, it does not show the direction of causality between physical activity and obesity. However, this evidence shows the vicious cycle between obesity and physical inactivity.[35] The low number of obese individuals meeting the recommendations and their low starting level (with regard to total amount, duration, and intensity) should be taken into account when tailoring interventions for increasing physical activity. For obese individuals, the amount of MPA, or perhaps low intensity activity, should be increased first. Among obese individuals, objectively measured physical activity seems to be low both during leisure and at work. Thus, both leisure hours and working hours need attention when tailoring activity interventions. Overall, the documentation of physical activity levels as a part of routine health care should be improved.[36]

Unanswered questions and future research

In light of our findings, long-term controlled intervention studies are needed to show whether MPA or VPA as the main component of intervention programs has a better benefit-risk balance among obese individuals in terms of adherence, weight-control, morbidity, and mortality. Also, more detailed research is needed on whether short bouts of physical activity lead to long-term health benefits comparable to longer bouts at the disease-outcome level. Accurate methods of monitoring physical activity that cover cardio-respiratory loading are also needed to carry out large-scale studies on these topics and to analyze whether specific types of short-term activity provide health benefits. Notably, some physical activity is under the intensity level of 3 METs, which was not taken into account in our current analysis. Long-term intervention studies on the effects of physical activity with (very) low intensity on disease outcomes are lacking.

Footnotes

We thank Firstbeat Technologies Ltd for providing the data for analysis. We also thank Kaisa Hämäläinen, Jaakko Kotisaari, and Tero Myllymäki, Firstbeat Technologies Ltd, for their assistance in the first stages of data mining and their valuable comments on the methods section of this paper.

Contributors: All authors participated in planning the study design and statistical analyses, revision of the manuscript, and approved the final version. SM and UMK (guarantor) drafted the manuscript. EH and JP carried out the analysis. All researchers were independent of the funders. The study sponsor and funder played no role in study design; the collection, analysis, and interpretation of data; the writing of the report; and the decision to submit the article for publication.

Funding: This work was partially supported by the SalWe Research Program for Mind and Body (Tekes - the Finnish Funding Agency for Technology and Innovation grant 1104/10).

Ethical approval: This study was approved by the Ethics Committee of Tampere University Hospital (Reference No R13160).

Competing interests: All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure .pdf and declare: all authors had financial support from Tekes (The Finnish Funding Agency for Innovation) for the submitted work; EH, JP and IK report research grant from Firstbeat Technologies Ltd, during the conduct of the study; EH, JP and IK report other research grant from Firstbeat Technologies Ltd, outside the submitted work; and IK is a co-founder in PulseOn Ltd which is a company developing optical heart rate monitoring technology, www.pulseon.com; other authors report no financial relationships with any organizations that might have an interest in the submitted work in the past three

years; other authors report no other relationships or activities that could appear to have influenced the submitted work.

Transparency: The lead author (the manuscript's guarantor) affirms that the manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

Data sharing: No additional data available.

An Exclusive licence: The Corresponding Author has the right to grant on behalf of all authors and does grant on behalf of all authors, a worldwide licence (http://www.bmj.com/sites/default/files/BMJ%20Author%20Licence%20March%202013.doc) to the Publishers and its licensees in perpetuity, in all forms, formats and media (whether known now or created in the future), to i) publish, reproduce, distribute, display and store the Contribution, ii) translate the Contribution into other languages, create adaptations, reprints, include within collections and create summaries, extracts and/or, abstracts of the Contribution and convert or allow conversion into any format including without limitation audio, iii) create any other derivative work(s) based in whole or part on the Contribution, iv) to exploit all subsidiary rights that currently exist or as may exist in the future in the Contribution, v) the inclusion of electronic links from the Contribution to third party material where-ever it may be located; and, vi) licence any third party to do any or all of the above. All research articles will be made available on an Open Access basis (with authors being asked to pay an open access fee—see http://www.bmj.com/about-bmj/resources-authors/forms-policies-and-checklists/copyright-open-access-and-permission-reuse). The terms of such Open Access shall be governed by a Creative Commons licence—details as to which Creative Commons

licence will apply to the research article are set out in our worldwide licence referred to above.

References

1. Pan XR, Li GW, Hu YH, Wang JX, Yang WY, An ZX, et al. Effects of diet and exercise in preventing NIDDM in people with impaired glucose tolerance. The Da Qing IGT and Diabetes Study. *Diabetes Care* 1997;20:537-44.
2. Ohkawara K, Tanaka S, Miyachi M, Ishikawa-Takata K, Tabata I. A dose-response relation between aerobic exercise and visceral fat reduction: Systematic review of clinical trials. *Int J Obes* 2007;31:1786-97.
3. Physical Activity Guidelines Advisory Committee. Physical Activity Guidelines Advisory Committee Report, 2008. Washington, DC: U.S. Department of Health and Human Services; 2008.
4. Waller K, Kaprio J, Lehtovirta M, Silventoinen K, Koskenvuo M, Kujala UM. Leisure-time physical activity and type 2 diabetes during a 28-year follow-up in twins. *Diabetologia* 2010;53:2531-7.
5. Kujala UM, Mäkinen V-P, Heinonen I, Soininen P, Kangas AJ, Leskinen TH, et al. Long-term leisure-time physical activity and serum metabolome. *Circulation* 2013;127:340-8.
6. Sattelmair J, Pertman J, Ding EL, Kohl III HW, Haskell W, Lee I-M. Dose response between physical activity and risk of coronary heart disease. A meta-analysis. *Circulation* 2011;124:789-95.
7. Li J, Siegrist J. Physical activity and risk of cardiovascular disease - A meta-analysis of prospective cohort studies. *Int J Environ Res Public Health* 2012;9:391-407.
8. Reiner M, Niermann C, Jekauc D, Woll A. Long-term health benefits of physical activity - A systematic review of longitudinal studies. *BMC Public Health* 2013;13:813.
9. Mammen G, Faulkner G. Physical activity and the prevention of depression. A systematic review of prospective studies. *Am J Prev Med* 2013;45:649-57.

10. Samitz G, Egger M, Zwahlen M. Domains of physical activity and all-cause mortality: Systematic review and dose-response meta-analysis of cohort studies. *Int J Epidemiol* 2011;40:1382-1400.

11. World Health Organization. Global recommendations on physical activity for health. Geneva: World Health Organization; 2010.

12. Garber CE, Blissmer B, Deschenes MR, Franklin BA, Lamonte MJ, Lee I-M, et al. American College of Sports Medicine Position Stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: Guidance for prescribing exercise. *Med Sci Sports Exerc* 2011, 1334-59. doi:10.1249/MSS.0b013e318213fefb

13. Butte NF, Ekelund U, Westerterp KR. Assessing physical activity using wearable monitors: Measures of physical activity. *Med Sci Sports Exerc* 2012;44:S5-S12.

14. Archer E, Hand GA, Hébert JR, Lau EY, Wang X, Shook RP, et al. Validation of a novel protocol for calculating estimated energy requirements and average daily physical activity ratio for the US population: 2005-2006. *Mayo Clin Proc* 2013;88:1398-1407.

15. Westerterp KR. Assessment of physical activity: A critical appraisal. *Eur J Appl Physiol* 2009;105:823-8.

16. Hagströmer M, Oja P, Sjöström M. Physical activity and inactivity in an adult population assessed by accelerometry. *Med Sci Sports Exerc* 2007;39:1502-8.

17. Tucker JM, Welk GJ, Beyler NK. Physical activity in U.S. adults. Compliance with the Physical Activity Guidelines for Americans. *Am J Prev Med* 2011;40:454-61.

18. Hansen BH, Holme I, Anderssen SA, Kolle E. Patterns of objectively measured physical activity in normal weight, overweight, and obese individuals (20-85 years): A cross-sectional study. *PLos ONE* 2013;8(1):e53044. doi:10.1371/journal.pone.0053044

19. Achten J, Jeukendrup AE. Heart rate monitoring. Applications and limitations. *Sports Med* 2003;33:517-38.

20. Smolander J, Ajoviita M, Juuti T, Nummela A, Rusko H. Estimating oxygen consumption from heart rate and heart rate variability without individual calibration. *Clin Physiol Funct Imaging* 2011;31:266-71.

21. Teisala T, Mutikainen S, Tolvanen A, Rottensteiner M, Leskinen T, Kaprio J, et al. Associations of physical activity, fitness, and body composition with heart rate variability-based indicators of stress and recovery on workdays: A cross-sectional study. *J Occup Med Toxicol* 2014;9:16. doi:10.1186/1745-6673-9-16

22. Firstbeat Technologies Ltd. EPOC based training effect assessment [White paper]. Published Sep 2005, updated March 2012. Available from: http://www.firstbeat.com/userData/firstbeat/download/white_paper_training_effect.pdf

23. Ross RM, Jackson AS. Exercise concepts, calculations, and computer applications. Carmel, Indiana: Benchmark press; 1990.

24. Jones NL. Clinical exercise testing. 3rd ed. Philadelphia: W.B. Saunders; 1988.

25. Jackson AS, Blair SN, Mahar MT, Wier LT, Ross RM, Stuteville JE. Prediction of functional aerobic capacity without exercise testing. *Med Sci Sports Exerc* 1990;22:863-70.

26. Saalasti S. Neural networks for heart rate time series analysis [dissertation]. Jyväskylä, Finland: University of Jyväskylä; 2003. Available from: https://jyx.jyu.fi/dspace/bitstream/handle/123456789/13267/951391707X.pdf?sequence=1

27. Kettunen J, Saalasti S, inventors; Firstbeat Technologies Ltd, assignee. Procedure for deriving reliable information on respiratory activity from heart period measurement. United States patent US 7,460,901 B2. 2008 Dec 2. Available from: http://worldwide.espacenet.com/publicationDetails/originalDocument?CC=US&NR=7460901B2&KC=B2&FT=D&ND=4&date=20081202&DB=EPODOC&locale=fi_FI

28. Kettunen J, Saalasti S, inventors; Firstbeat Technologies Ltd, assignee. Procedure for detection of stress by segmentation and analyzing heart beat signal. United States patent US 7,330,752 B2. 2008 Feb 12. Available from: http://worldwide.espacenet.com/publicationDetails/originalDocument?FT=D&date=20080212&DB=EPODOC&locale=fi_FI&CC=US&NR=7330752B2&KC=B2&ND=4

29. Firstbeat Technologies Ltd. VO_2 estimation method based on heart rate measurement [White paper]. Published Feb 2005, updated March 2012. Available from: http://www.firstbeat.com/userData/firstbeat/download/white_paper_vo2_estimation.pdf

30. Kang M, Bassett DR, Barreira TV, Tudor-Locke C, Ainsworth B, Reis JP, et al. How many days are enough? A study of 365 days of pedometer monitoring. *Res Q Exerc Sport* 2009;80:445-53.

31. Troiano RP, Berrigan D, Dodd KW, Mâsse LC, Tilert T, McDowell M. Physical activity in the United States measured by accelerometer. *Med Sci Sports Exerc* 2008;40:181-8.

32. Husu P, Suni J, Vähä-Ypyä H, Sievänen H, Tokola K, Valkeinen H, et al. The level of physical activity and sedentary behaviour in Finnish adults. *Suomen Lääkärilehti* 2014;69:1860-6. (in Finnish; abstract available in English).

33. Helakorpi S, Laitalainen E, Uutela A. Health behaviour and health among the Finnish adult population, spring 2009. National Institute for Health and Welfare (THL), Report 7/2010. (in Finnish; abstract, tables and figures available in English).

34. Hu FB, Willett WC, Li T, Stampfer MJ, Colditz GA, Manson JE. Adiposity as compared with physical activity in predicting mortality among women. *N Engl J Med* 2004;351:2694-703.

35. Pietiläinen KH, Kaprio J, Borg P, Plasqui G, Yki-Järvinen H, Kujala UM, et al. Physical inactivity and obesity: A vicious circle. *Obesity* 2008;16:409-14.

36. Strath SJ, Kaminsky LA, Ainsworth BE, Ekelund U, Freedson PS, Gary RA, et al. Guide to the assessment of physical activity: Clinical and research applications: A scientific statement from the American Heart Association. *Circulation* 2013;128:2259-79.

Table 1 Distributions of participants into moderate-to-vigorous and vigorous physical activity categories according to mean minutes per day on workdays and days off

	Workdays				Days off			
	0 min n (%)	**>0-15 min n (%)**	**>15-30 min n (%)**	**>30 min n (%)**	**0 min n (%)**	**>0-15 min n (%)**	**>15-30 min n (%)**	**>30 min n (%)**
Men (n=4221)								
$MVPA_{1min}$	91 (2.2)	835 (19.8)	706 (16.7)	2589 (61.3)	160 (3.8)	851 (20.2)	563 (13.3)	2647 (62.7)
$MVPA_{10min}$	1345 (31.9)	712 (16.9)	802 (19.0)	1362 (32.3)	1535 (36.4)	452 (10.7)	500 (11.8)	1734 (41.1)
VPA_{1min}	1544 (36.6)	1571 (37.2)	658 (15.6)	448 (10.6)	1862 (44.1)	1221 (28.9)	391 (9.3)	747 (17.7)
VPA_{10min}	3014 (71.4)	524 (12.4)	441 (10.4)	242 (5.7)	3189 (75.6)	236 (5.6)	292 (6.9)	504 (11.9)
Women (n=5333)								
$MVPA_{1min}$	480 (9.0)	1632 (30.6)	1015 (19.0)	2206 (41.4)	838 (15.7)	1612 (30.2)	760 (14.3)	2123 (39.8)
$MVPA_{10min}$	2523 (47.3)	913 (17.1)	864 (16.2)	1033 (19.4)	2999 (56.2)	469 (8.8)	550 (10.3)	1315 (24.7)
VPA_{1min}	3200 (60.0)	1454 (27.3)	440 (8.3)	239 (4.5)	3651 (68.5)	979 (18.4)	299 (5.6)	404 (7.6)
VPA_{10min}	4520 (84.8)	408 (7.7)	294 (5.5)	111 (2.1)	4690 (87.9)	196 (3.7)	169 (3.2)	278 (5.2)

$MVPA_{1min}$=moderate-to-vigorous physical activity (≥3 metabolic equivalents [METs]) calculated from single 1-minute bouts throughout the measurement period

$MVPA_{10min}$= moderate-to-vigorous physical activity (≥3 METs) calculated from bouts of physical activity lasting continuously for ≥10 minutes

VPA_{1min}=vigorous physical activity (≥6 METs) calculated from single 1-minute bouts throughout the measurement period

VPA_{10min}=vigorous physical activity (≥6 METs) calculated from bouts of physical activity lasting continuously for ≥10 minutes

Table 2 Amount of moderate-to-vigorous and vigorous physical activity during workdays and days off based on age group

	n (men/women)		Men: Workdays (min/day)	Men: Days off (min/day)	Men: P*	Women: Workdays (min/day)	Women: Days off (min/day)	Women: P*
$MVPA_{1min}$								
18-30 yrs	366/457	mean (SD)	88.6 (72.8)†	88.3 (75.7)†	0.81	76.6 (53.5)†	71.5 (61.9)†	0.005
		median	67.5†	69.0†		69.0†	60.0†	
31-40 yrs	1109/1251	mean (SD)	55.7 (44.2)†	67.7 (63.2)†	<0.001	42.1 (38.5)†	40.8 (40.6)†	0.041
		median	47.0†	52.3†		34.0†	28.0†	
41-50 yrs	1411/1905	mean (SD)	47.1 (42.5)†	59.9 (56.5)†	<0.001	28.3 (29.1)†	31.1 (37.1)†	0.34
		median	36.5†	47.0†		21.0†	17.0†	
51-65 yrs	1335/1720	mean (SD)	42.9 (46.2)†	53.3 (56.0)†	<0.001	20.5 (24.4)†	22.7 (33.3)†	0.74
		median	31.0†	37.5†		11.0†	8.0†	
VPA_{1min}								
18-30 yrs	366/457	mean (SD)	17.0 (21.4)†	17.6 (25.3)†	0.73	16.5 (19.9)†	15.1 (23.1)†	0.004
		median	10.0†	5.0†		9.0†	4.0†	
31-40 yrs	1109/1251	mean (SD)	11.6 (16.6)†	15.9 (24.4)†	<0.001	7.8 (12.7)†	8.1 (15.9)†	0.16
		median	4.0†	3.0†		1.0†	0.0†	
41-50 yrs	1411/1905	mean (SD)	9.9 (14.7)†	13.9 (24.9)†	<0.001	4.0 (9.1)†	5.8 (14.9)†	0.008
		median	2.0†	1.0†		0.0†	0.0†	
51-65 yrs	1335/1720	mean (SD)	7.4 (13.9)†	10.2 (21.2)†	0.003	1.8 (6.3)†	2.5 (11.2)†	0.54
		median	0.5†	0.0†		0.0†	0.0†	

* For the difference between workdays and days off by Wilcoxon two-sample paired signed rank test

† P<0.001 for the difference between age groups by Kruskal-Wallis test

$MVPA_{1min}$=moderate-to-vigorous physical activity (≥3 metabolic equivalents [METs]) calculated from single 1-minute bouts throughout the measurement period

VPA_{1min}=vigorous physical activity (≥6 METs) calculated from single 1-minute bouts throughout the measurement period

Table 3 Amount of moderate-to-vigorous and vigorous physical activity during workdays and days off based on weight status

	n (men/women)		Men Workdays (min/day)	Men Days off (min/day)	Men P*	Women Workdays (min/day)	Women Days off (min/day)	Women P*
$MVPA_{1min}$								
Normal weight	1495/2792	mean (SD)	60.1 (53.5)†	74.0 (67.4)†	<0.001	44.5 (39.6)†	46.4 (46.7)†	0.99
		median	48.0†	58.5†		35.5†	35.0†	
Overweight	2067/1627	mean (SD)	49.4 (46.2)†	60.0 (56.4)†	<0.001	24.5 (30.1)†	25.2 (33.0)†	0.60
		median	38.0†	46.0†		16.0†	12.0†	
Obese	659/914	mean (SD)	39.6 (43.5)†	42.9 (52.0)†	0.18	13.9 (21.3)†	12.6 (21.8)†	0.001
		median	29.0†	26.0†		4.8†	2.0†	
VPA_{1min}								
Normal weight	1495/2792	mean (SD)	13.2 (17.3)†	18.2 (27.4)†	<0.001	8.4 (13.8)†	10.0 (19.2)†	0.65
		median	5.5†	4.0†		1.0†	0.0†	
Overweight	2067/1627	mean (SD)	9.6 (15.5)†	12.6 (22.3)†	<0.001	2.5 (7.9)†	2.6 (9.1)†	0.44
		median	1.5†	1.0†		0.0†	0.0†	
Obese	659/914	mean (SD)	5.0 (11.3)†	6.1 (16.3)†	0.97	0.6 (3.1)†	0.5 (3.5)†	0.07
		median	0.0†	0.0†		0.0†	0.0†	

Normal weight=18.5 to <25.0 kg/m^2; overweight=25.0 to <30.0 kg/m^2; obese=30.0 to 40.0 kg/m^2

* For the difference between workdays and days off by Wilcoxon two-sample paired signed rank test

† P<0.001 for the difference between body mass index groups by Kruskal-Wallis test

$MVPA_{1min}$=moderate-to-vigorous physical activity (≥3 metabolic equivalents [METs]) calculated from single 1-minute bouts throughout the measurement period

VPA_{1min}=vigorous physical activity (≥6 METs) calculated from single 1-minute bouts throughout the measurement period

Table 4 Predictors of the amount of moderate-to-vigorous and vigorous physical activity

	$MVPA_{1min}$		VPA_{1min}	
	Unstandardized regression coefficient (95% CI)	**P**	**Unstandardized regression coefficient (95% CI)**	**P**
Age (18 yrs=0)	-1.130 (-1.203 to -1.056)	<0.001	-0.286 (-0.310 to -0.261)	<0.001
Gender (1=men; 0=women)	24.352 (22.930 to 25.773)	<0.001	6.584 (6.114 to 7.054)	<0.001
Body mass index (18.5 kg/m^2=0)	-2.464 (-2.639 to -2.288)	<0.001	-0.762 (-0.820 to -0.704)	<0.001
Type of day (1=workday; 0=day off)	-5.161 (-6.051 to -4.271)	<0.001	-1.934 (-2.312 to -1.556)	<0.001

$MVPA_{1min}$=moderate-to-vigorous physical activity (≥3 metabolic equivalents [METs]) calculated from single 1-minute bouts throughout the measurement period

VPA_{1min}=vigorous physical activity (≥6 METs) calculated from single 1-minute bouts throughout the measurement period

The dependent variables in the linear mixed effects regression models were $MVPA_{1min}$ and VPA_{1min} (minutes/day) as continuous variables.

Table 5 Probability of having a bout of moderate-to-vigorous or vigorous physical activity (per measurement day) lasting continuously for ≥10 minutes

	MVPA		VPA	
	Unstandardized regression coefficient (95% CI)	P	Unstandardized regression coefficient (95% CI)	P
Simple models				
Age (18 yrs=0)	-0.040 (-0.043 to -0.036)	<0.001	-0.047 (-0.052 to -0.042)	<0.001
Gender (1=men; 0=women)	0.948 (0.881 to 1.016)	<0.001	1.263 (1.163 to 1.363)	<0.001
Body mass index (18.5 kg/m^2=0)	-0.139 (-0.148 to -0.130)	<0.001	-0.186 (-0.202 to -0.171)	<0.001
Type of day (1=workday; 0=day off)	-0.189 (-0.242 to -0.135)	<0.001	-0.244 (-0.322 to -0.167)	<0.001
Interaction models				
Age (18 yrs=0)	-0.023 (-0.031 to -0.014)	<0.001	-0.032 (-0.043 to -0.021)	<0.001
Gender (1=men; 0=women)	-0.157 (-0.400 to 0.086)	0.21	-0.764 (-1.100 to -0.427)	<0.001
Body mass index (18.5 kg/m^2=0)	-0.078 (-0.107 to -0.050)	<0.001	-0.126 (-0.170 to -0.081)	<0.001
Type of day (1=workday; 0=day off)	0.135 (-0.049 to 0.319)	0.15	0.004 (-0.231 to 0.240)	0.97
Age*Body mass index	-0.003 (-0.004 to -0.002)	<0.001	-0.006 (-0.008 to -0.004)	<0.001
Gender*Age	0.030 (0.022 to 0.037)	<0.001	0.058 (0.047 to 0.068)	<0.001
Gender*Body mass index	0.068 (0.050 to 0.086)	<0.001	0.116 (0.085 to 0.147)	<0.001
Type of day*Age	-0.009 (-0.015 to -0.004)	0.001	-0.016 (-0.024 to -0.008)	<0.001
Type of day*Gender	-0.349 (-0.460 to -0.238)	<0.001	-0.188 (-0.364 to -0.013)	0.035
Type of day*Body mass index	0.012 (-0.003 to 0.027)	0.12	0.040 (0.013 to 0.066)	0.003

MVPA=moderate-to-vigorous physical activity (≥3 metabolic equivalents [METs]); VPA=vigorous physical activity (≥6 METs)

The results are from the generalized linear mixed effects regression models in which the dependent variables are binary outcomes (participant did or did not have a bout of moderate-to-vigorous or vigorous physical activity lasting ≥10 minutes) and each participant is incorporated as a random effect. In the simple models, the fixed effects are age, gender, body mass index, and type of day. In the interaction models, the fixed effects are age, gender, body mass index, type of day, and all of their possible two-way interactions.

Table 6 Proportion of participants fulfilling the aerobic physical activity recommendation* based on gender and weight status

	Men	Women
	% (95% CI)	**% (95% CI)**
MVPA$_{1min}$		
All	80.0 (78.8 to 81.2)	56.1 (54.7 to 57.4)
Normal weight	88.6 (86.8 to 90.1)	74.1 (72.4 to 75.7)
Overweight	79.4 (77.6 to 81.1)	43.8 (41.3 to 46.2)
Obese	62.5 (58.7 to 66.2)	23.0 (20.3 to 25.8)
MVPA$_{10min}$		
All	54.3 (52.8 to 55.8)	32.8 (31.6 to 34.1)
Normal weight	64.9 (62.4 to 67.3)	46.5 (44.6 to 48.3)
Overweight	52.7 (50.5 to 54.9)	22.1 (20.1 to 24.2)
Obese	35.5 (31.9 to 39.3)	10.3 (8.4 to 12.4)

* Moderate intensity aerobic physical activity at least 150 minutes per week, vigorous physical activity at least 75 minutes per week, or a combination of these (for details of calculation, see methods)

Normal weight=18.5 to <25.0 kg/m^2; overweight=25.0 to <30.0 kg/m^2; obese=30.0 to 40.0 kg/m^2

MVPA$_{1min}$= moderate-to-vigorous physical activity (≥3 metabolic equivalents [METs]) calculated from single 1-minute bouts throughout the measurement period

MVPA$_{10min}$= moderate-to-vigorous physical activity (≥3 METs) calculated from bouts of physical activity lasting continuously for ≥10 minutes

Figure legends

Figure 1 Flow of participants and measurement days included in the analysis.

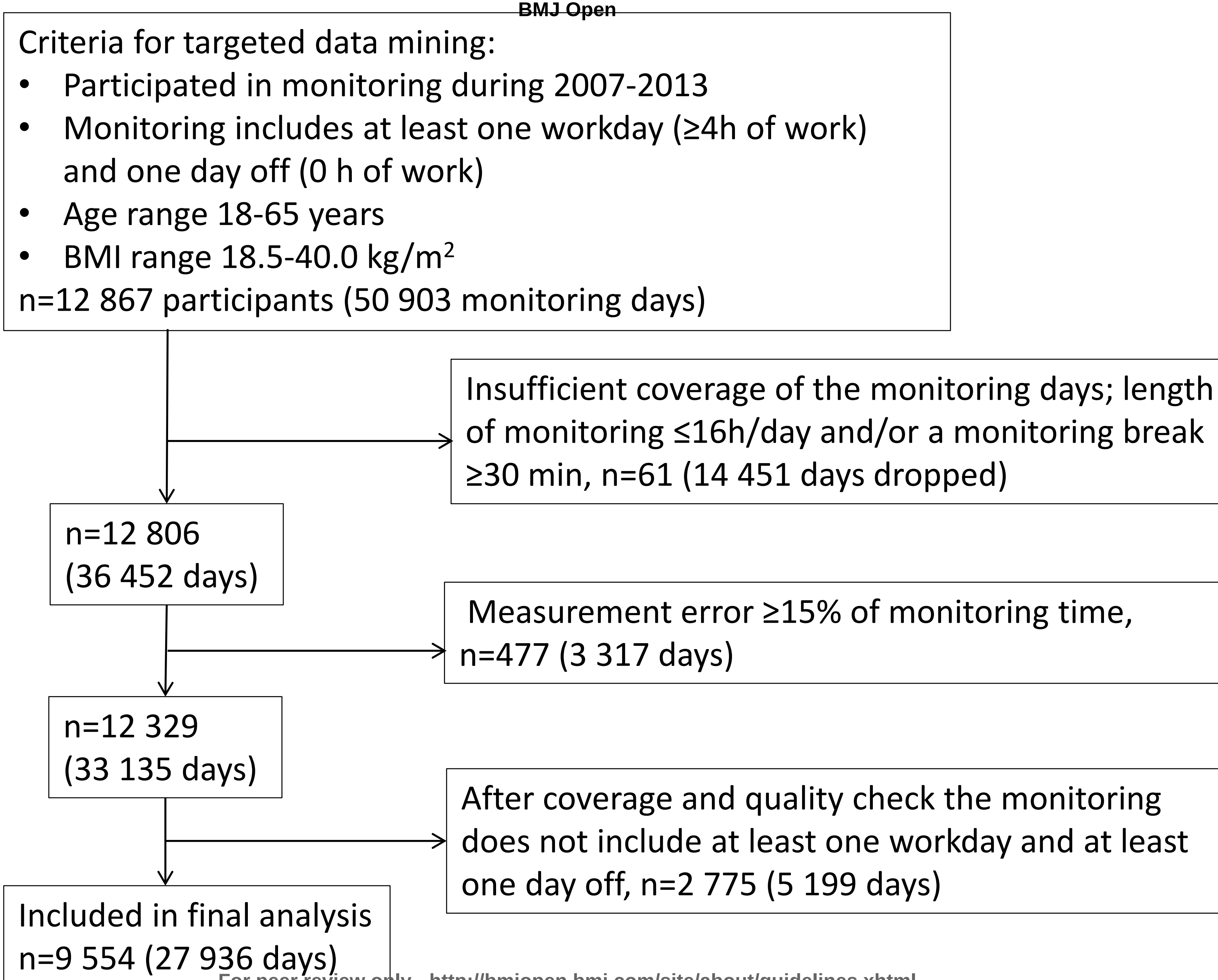
Figure 2 The mean amount of moderate-to-vigorous physical activity (≥3 metabolic equivalents [METs]) (whole column) and its distribution into moderate (MPA; 3 to <6 METs) and vigorous (VPA; ≥6 METs) physical activity during workdays (WD) and days off (DO) by age among men and women. The 1 min notation indicates values for single 1-minute bouts throughout the measurement period, whereas the 10 min notation indicates values for bouts of physical activity lasting continuously for ≥10 minutes. P_3 and P_6 denote the differences between WD and DO in moderate-to-vigorous and vigorous physical activities, respectively. *physical activity was greater during WD than DO. Note the different scales between the upper and lower figures.

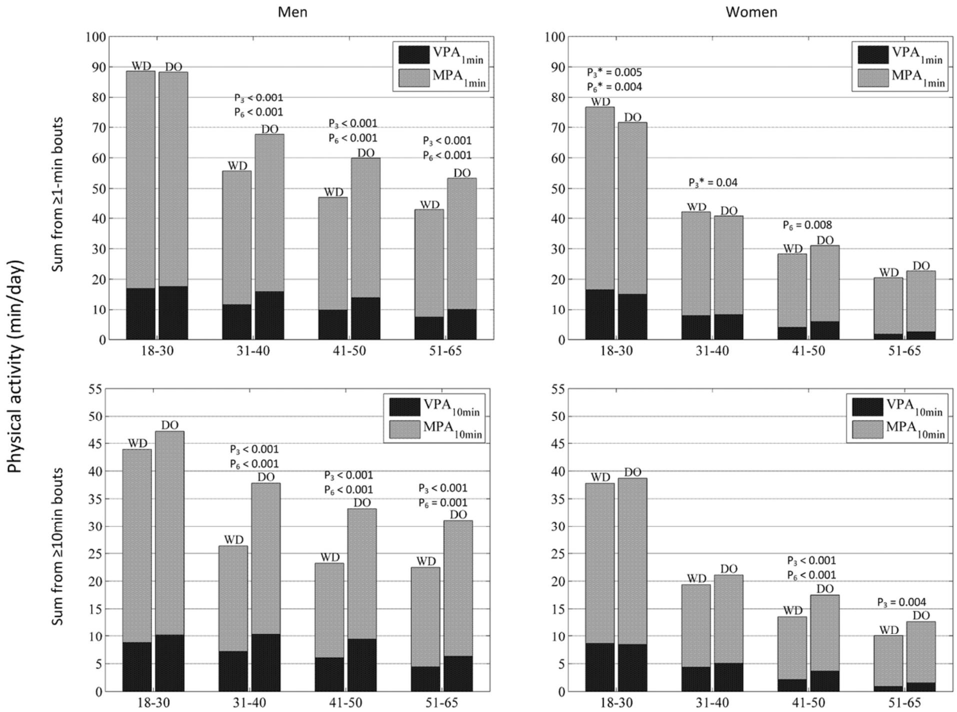
Figure 3 The mean amount of moderate-to-vigorous physical activity (≥3 metabolic equivalents [METs]) (whole column) and its distribution into moderate (MPA; 3 to <6 METs) and vigorous (VPA; ≥6 METs) physical activity during workdays (WD) and days off (DO) by weight status among men and women. Normal weight=18.5 to <25.0 kg/m^2; overweight=25.0 to <30.0 kg/m^2; obese=30.0 to 40.0 kg/m^2. The 1 min notation indicates values for single 1-minute bouts throughout the measurement period, whereas the 10 min notation indicates values for bouts of physical activity lasting continuously for ≥10 minutes. P_3 and P_6 denote the differences between WD and DO in moderate-to-vigorous and vigorous physical activities, respectively. *physical activity was greater during WD than DO. Note the different scales between the upper and lower figures.

Figure 4 Hourly distributions of moderate-to-vigorous (MVPA; ≥3 metabolic equivalents [METs]) and vigorous (VPA; ≥6 METs) physical activity by gender and weight status during workdays and days off. The mean number of minutes at a certain hour (e.g., 9 am) denotes

the number of minutes during the hour beginning from that time point (e.g., 9-10 am). Normal weight=18.5 to <25.0 kg/m^2; overweight=25.0 to <30.0 kg/m^2; obese=30.0 to 40.0 kg/m^2. The 1 min notation indicates values for single 1-minute bouts throughout the measurement period.

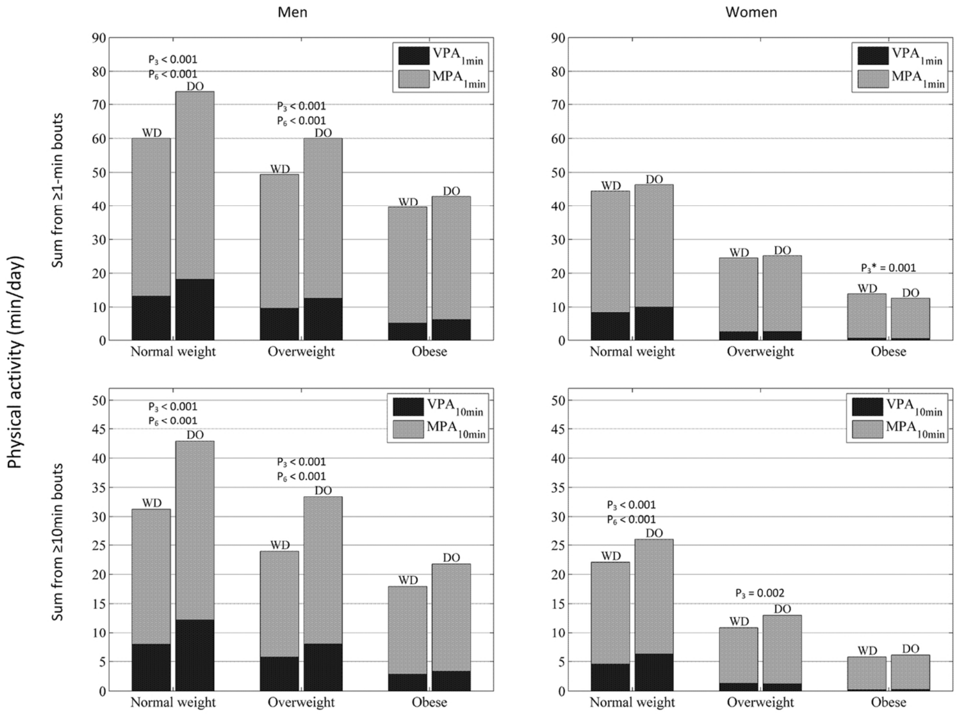
Figure 5 The proportion of participants fulfilling the aerobic physical activity recommendation (moderate intensity physical activity for at least 150 minutes per week, vigorous physical activity at least 75 minutes per week, or a combination of these) based on gender and weight status. Normal weight=18.5 to <25.0 kg/m^2; overweight=25.0 to <30.0 kg/m^2; obese=30.0 to 40.0 kg/m^2. Note the different scales between the upper and lower figures.


Criteria for targeted data mining:
• Participated in monitoring during 2007-2013
• Monitoring includes at least one workday (≥4h of work) and one day off (0 h of work)
• Age range 18-65 years
• BMI range 18.5-40.0 kg/m²
n=12 867 participants (50 903 monitoring days)
Insufficient coverage of the monitoring days; length of monitoring ≤16h/day and/or a monitoring break ≥30 min, n=61 (14 451 days dropped)
n=12 806 (36 452 days)
Measurement error ≥15% of monitoring time, n=477 (3 317 days)
n=12 329 (33 135 days)
After coverage and quality check the monitoring does not include at least one workday and at least one day off, n=2 775 (5 199 days)
Included in final analysis n=9 554 (27 936 days)

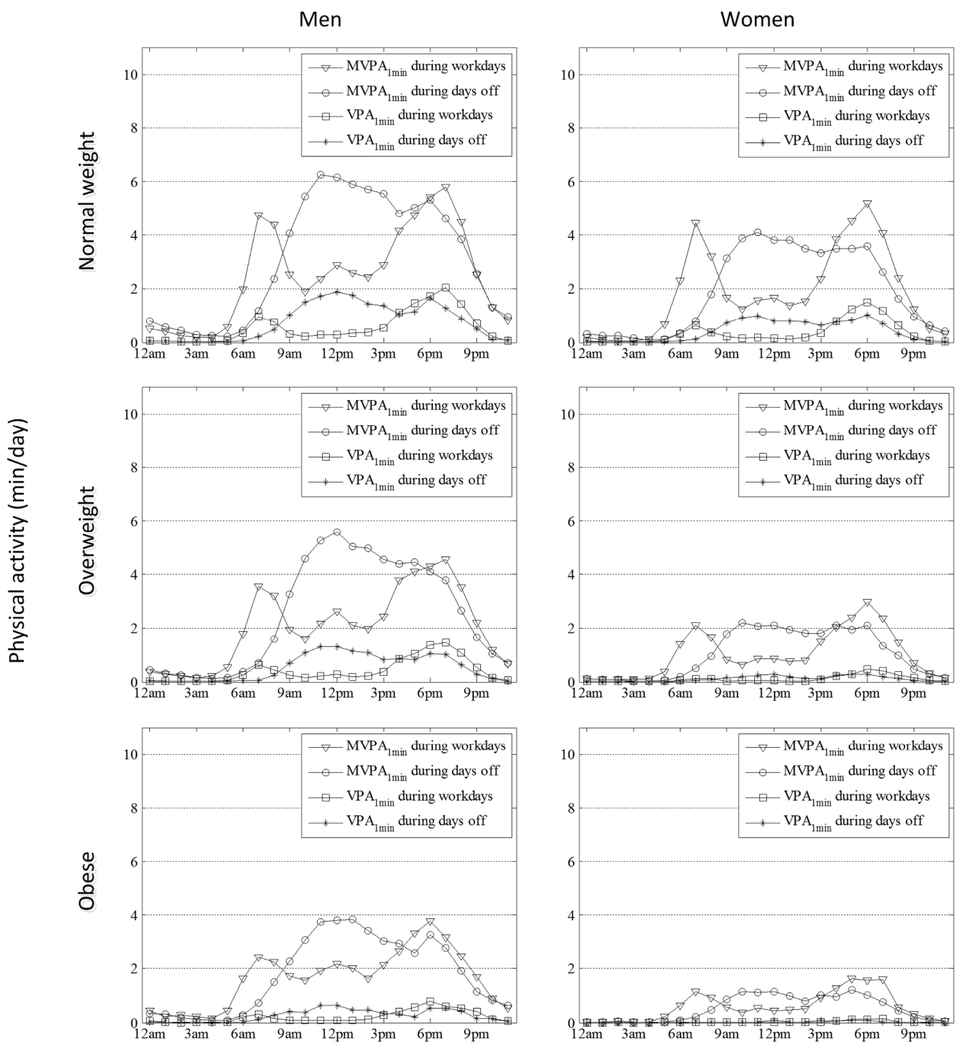


The mean amount of moderate-to-vigorous physical activity (≥3 metabolic equivalents [METs]) (whole column) and its distribution into moderate (MPA; 3 to <6 METs) and vigorous (VPA; ≥6 METs) physical activity during workdays (WD) and days off (DO) by age among men and women. The 1 min notation indicates values for single 1-minute bouts throughout the measurement period, whereas the 10 min notation indicates values for bouts of physical activity lasting continuously for ≥10 minutes. P3 and P6 denote the differences between WD and DO in moderate-to-vigorous and vigorous physical activities, respectively. *physical activity was greater during WD than DO. Note the different scales between the upper and lower figures.

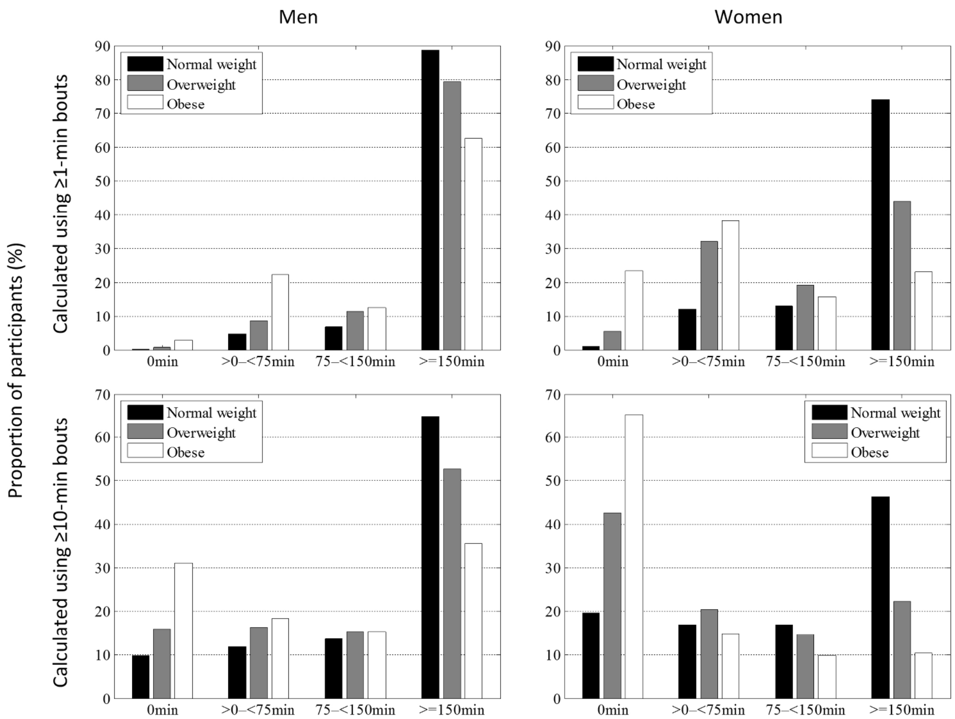
130x97mm (300 x 300 DPI)



The mean amount of moderate-to-vigorous physical activity (≥3 metabolic equivalents [METs]) (whole column) and its distribution into moderate (MPA; 3 to <6 METs) and vigorous (VPA; ≥6 METs) physical activity during workdays (WD) and days off (DO) by weight status among men and women. Normal weight=18.5 to <25.0 kg/m2; overweight=25.0 to <30.0 kg/m2; obese=30.0 to 40.0 kg/m2. The 1 min notation indicates values for single 1-minute bouts throughout the measurement period, whereas the 10 min notation indicates values for bouts of physical activity lasting continuously for ≥10 minutes. P3 and P6 denote the differences between WD and DO in moderate-to-vigorous and vigorous physical activities, respectively. *physical activity was greater during WD than DO. Note the different scales between the upper and lower figures.
130x97mm (300 x 300 DPI)



Hourly distributions of moderate-to-vigorous (MVPA; ≥3 metabolic equivalents [METs]) and vigorous (VPA; ≥6 METs) physical activity by gender and weight status during workdays and days off. The mean number of minutes at a certain hour (e.g., 9 am) denotes the number of minutes during the hour beginning from that time point (e.g., 9-10 am). Normal weight=18.5 to <25.0 kg/m2; overweight=25.0 to <30.0 kg/m2; obese=30.0 to 40.0 kg/m2. The 1 min notation indicates values for single 1-minute bouts throughout the measurement period.
182x193mm (300 x 300 DPI)



The proportion of participants fulfilling the aerobic physical activity recommendation (moderate intensity physical activity for at least 150 minutes per week, vigorous physical activity at least 75 minutes per week, or a combination of these) based on gender and weight status. Normal weight=18.5 to <25.0 kg/m2; overweight=25.0 to <30.0 kg/m2; obese=30.0 to 40.0 kg/m2. Note the different scales between the upper and lower figures.

198x147mm (300 x 300 DPI)

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract SEE PAGES 1- 2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found SEE PAGES 1- 2
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported SEE PAGES 5-6
Objectives	3	State specific objectives, including any prespecified hypotheses SEE PAGE 6
Methods		
Study design	4	Present key elements of study design early in the paper SEE ABSTRACT AND PAGE 6-
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection SEE PAGE 6
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants SEE PAGES 6-7 AND FIGURE 1
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable DEFINED IN METHODS
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group DEFINED IN METHODS
Bias	9	Describe any efforts to address potential sources of bias WE HAVE ANALYZED THAT DIFFERENT STEPS IN DATA MINING SUCH AS FOCUSING ONLY TO THOSE WHO HAVE RECORDINGS FROM DAYS OFF AND WORKDAYS DO NOT CHANGE THE RESULTS. COMPLETE DISCUSSION ON ALL ANALYSES DONE FOR THIS PURPOSE COULD NOT BE INCLUDED IN THE PAPER, SHORT COMMENT IN DISCUSSION
Study size	10	Explain how the study size was arrived at AVAILABLE DATA FOR DATA MINING, VERY BIG DATASET, EXPLAINED IN METHODS
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why DEFINED IN METHODS
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding DEFINED IN STATISTICAL METHODS
		(*b*) Describe any methods used to examine subgroups and interactions DEFINED IN STATISTICAL METHODS
		(*c*) Explain how missing data were addressed EXPLAINED IN METHODS AND

		FLOW CHART
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy EXPLAINED IN METHODS
		(*e*) Describe any sensitivity analyses
Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed DEFINED IN METHODS AND FIGURE 1
		(b) Give reasons for non-participation at each stage DEFINED IN METHODS AND FIGURE 1
		(c) Consider use of a flow diagram SEE FIGURE 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders GIVEN IN METHODS AND THE BEGINNING OF RESULTS
		(b) Indicate number of participants with missing data for each variable of interest DEFINED IN METHODS AND FIGURE 1
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time
		Case-control study—Report numbers in each exposure category, or summary measures of exposure
		Cross-sectional study—Report numbers of outcome events or summary measures SEE TABLES
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included SEE ABSTRACT AND RESULTS
		(*b*) Report category boundaries when continuous variables were categorized REPORTED IN APPROPRIATE PLACES; METHODS, RESULTS, TABLES, FIGURES
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses SEE RESULTS
Discussion		
Key results	18	Summarise key results with reference to study objectives PAGES 14-15
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias PAGES 15-16
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence PAGES 14-15, DISCUSSION ELSEWHERE
Generalisability	21	Discuss the generalisability (external validity) of the study results PAGES 14-15, DISCUSSION ELSEWHERE
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based PAGE 20